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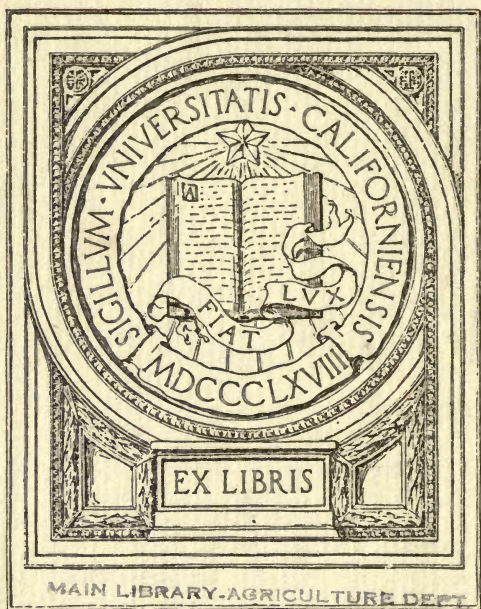


HORTICULTURE
FOR
SCHOOLS



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HORTICULTURE FOR SCHOOLS

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HORTICULTURE FOR SCHOOLS

BY

the late

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New York

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EXPLANATION

THE late Professor A. V. Stubenrauch was under contract at the time of his death to prepare an elementary text-book of horticulture, suitable for use in the schools and in reading-courses. Much of the material had been assembled by him. It has seemed best to bring the book to completion, preserving as much as possible of his method and point of view. This work has fallen to Milo N. Wood, who was personally associated with Professor Stubenrauch in his teaching; and the enterprise has been joined by Charles J. Booth, an active teacher of the subject in high-school.

Professor Stubenrauch was connected with the University of California at the time of his death. He was a graduate of that institution, a post-graduate of Cornell University, a professor in the University of Illinois, and later prominently connected with the United States Department of Agriculture in its country-wide pomological work. He was a man of wide friendships, solid personal attainments, inspiring teaching ability, and excellent qualifications for investigation. His death early in 1917, as he was entering the productive period of manhood, deprived the people of a forceful and dependable leader.

Another book was under preparation by Professor Stubenrauch, and it is intended that it shall be brought to completion. There are no other books bearing his name, although he had large plans as an author. It is not expected that these books can carry out his style and contain all his subject-matter; but his collaborators have been glad to do their best to complete his labors.

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PREFACE

This book is intended as a text-book of horticulture for high-schools and for other schools requiring a text for pupils of high-school grade, and also for use in homes and reading-courses. The subject-matter and exercises may be covered in one school year if three periods a week are spent in recitation and two double periods are employed for laboratory work. When a shorter period is given to the subject, it will be advisable to omit the chapters of least importance to the community.

It is not necessary that the chapters be studied in the order given in the text. The teacher should assign them in the order suggested by the climate, season, and needs of the locality. It is advisable, however, to take up chapters I and II before other subject-matter is considered, because an understanding of the material contained therein will result in a more thorough appreciation of the chapters following.

The exercises given at the ends of the chapters are intended as an aid to the busy teacher. They are of three types: (1) those that explain or illustrate the subject-matter in the text; (2) those that familiarize the pupils with the best horticultural practices; and (3) project exercises that require the pupils to apply the facts, principles, and methods of procedure in detail to the production and sale of a particular horticultural crop.

The project exercise is of great value in teaching the practical application of the general principles discussed in the text, and in teaching practical business methods as applied to horticulture. In general the project should be large enough to occupy the spare time of the student and

may be of such size as to be of considerable commercial or productive importance. Care should be taken, however, that the project is not so large that the student cannot care for it properly. While a few trees or a small plot of ground may not always supply the same aspects as would a large planting, the problems relating to successful production are, for practical purposes, identical. It is desirable that projects in horticulture be carried on by the student at home in coöperation with his parents and under the direction of the teacher of agriculture. Sometimes the necessary land and materials may be rented. The teacher should supervise the keeping of careful records of operations, expenses, and disposition of the products. Any financial or other returns should go to the student. Student projects on the school ground are generally to be discouraged. Orchards and gardens on the school grounds, however, are of great value as out-of-door laboratories in which the student may gain experience in horticultural practice. They may be of the school garden kind.

It is of great value to the student to have access to good reference literature. Bailey's Standard Cyclopedia of Horticulture (6 vols.) will be useful. Many valuable works on special horticultural topics are now available. The teacher should choose as reference books such of these works as seem best adapted to the needs of the locality. Such farmers' bulletins and technical publications on horticultural subjects as may be obtained from the United States Department of Agriculture and the State Experiment Stations are very helpful.

Special acknowledgment is due L. H. Bailey, for helpful counsel and valuable criticism; also to W. L. Howard, Professor of Pomology, University of California Deciduous-Fruit Experiment Station; J. W. Lloyd, Professor of Olericulture, University of Illinois; W. F. Lusk, Head of Department of Rural Education, Mississippi Agricultural and Mechanical College; W. P. Tufts, Professor of Pomology of

the University of California Farm School; J. C. Whitten, late Professor of Pomology, University of California; A. T. Potts, Professor of Vegetable Gardening in the Agricultural and Mechanical College of Texas; and T. J. Talbert, Superintendent of Extension Schools, Kansas Agricultural College, for reading and criticizing parts of the manuscript. George P. Weldon, Pomologist of the Chaffey Junior College gave valuable assistance in the preparation of the chapter on insects.

The line drawings were made specially for this book by R. C. Steadman of the United States Department of Agriculture, by B. F. Williamson of New York, and by Mary Mekeel, of Ithaca, N. Y. The University of California allowed the use of certain material prepared by the writers while they were connected with the institution, and supplied photographs. Several figures were taken from *School Agriculture*. A. D. Shamel of the United States Department of Agriculture furnished photographs; also H. S. Fawcett and H. J. Quayle of the Citrus Experiment Station of California, Porter J. Preston and L. S. Armstrong. Figures 2 and 25 were drawn by R. A. Hopkins, and figure 121 by A. A. Brown of Ontario, California. Figures 17, 29, 39, 111, 117, and 118 are taken from the publications of the Macmillan Company.

MILO N. WOOD.

CHARLES J. BOOTH.

September 1, 1922.

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HORTICULTURE FOR SCHOOLS

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CHAPTER I

HORTICULTURE AND PLANT IMPROVEMENT

THE word "horticulture" is derived from two Latin words, *hortus* and *cultura*. The first of these means a garden, originally in the Greek an inclosed space for plants; the second signifies care or cultivation. Literally, therefore, the combination suggests the care of a small inclosed area. However, the conditions of life change from generation to generation, and the meanings of words change also. Horticulture is now not a question of inclosures, or even of gardens. The original significance of the derivative is as out-of-date as is the wooden plow of the Romans.

1. Horticulture defined.—Horticulture is the growing of flowers, fruits, vegetables, and ornamental trees and shrubs. In the aggregate, it is an industry which engages the attention of a great many persons and which represents the outlay of large amounts of capital. From the limited beginnings connoted by the Latin roots, it has grown, in America, to the proportions of a business of great magnitude and has become a major affair in the agriculture of the country. In Europe, floriculture, or the raising of flowers, has received much attention for a long period. In America, fruit- and vegetable-growing have been especially emphasized, but ornamental gardening is gradually acquiring importance.

2. Plant material.—A brief investigation will show that many varieties of cultivated plants are grown. Of the apple alone, most popular and widespread of all our fruits, there

are more than one thousand varieties. Of the grape there are twice as many. Of peaches, more than two thousand varieties have been listed in the state of New York alone. There are many thousands of varieties of fruits and vegetables. The thoughtful student will at once wonder at this multiplicity of varieties. Whence have they all come? What purpose do they serve? Of what concern are they to the student of horticulture?

3. Varieties not permanent.—An historical study likewise reveals some interesting facts. Of the varieties of apples known two hundred years ago, only a few are found in the orchards of today. A variety has its period of popularity, being in time replaced by new sorts which fill new needs and thrive better under new conditions. Sometimes a form like the Newtown Pippin apple or the Concord grape remains for many years a standard, but these outstanding exceptions tend only to emphasize the general rule, that new varieties are constantly appearing and old ones are passing.

4. Change is universal.—This phenomenon of change is not limited to varieties of fruits. John Muir, in *Our National Parks*, expresses this universal law of life. "Nature is ever at work building and pulling down, creating and destroying, keeping everything whirling and flowing, allowing no rest but in rhythmical motion; chasing everything in endless song out of one beautiful form into another." He was thinking, when he wrote, of forests and meadows, of glaciers and streams, of what we are pleased to call "the everlasting mountains"; but his words are equally true of the cultivated forms of plants.

5. The nightshade family.—The nightshades illustrate the variety in form that plants exhibit and the way in which man has availed himself of this variety in search of food. The common black nightshade grows wild in all parts of the United States. With its small white or violet colored blos-

soms, and its fruits shading from green to black, it is found along roadsides and in uncultivated corners everywhere. It occurs in many forms. One species is very poisonous and bears the name "deadly nightshade" or more properly belladonna; it is not wild in North America, but many of the species found here contain drugs of greater or less toxic effect. There are many species of *Solanum*, which is the principal genus of the nightshade family. *Solanum nigrum*, variously known as black nightshade, stubbleberry, or garden huckleberry, and *Solanum carolinense* (the horse nettle) are two well-known plants of the genus; there are many kinds known as weeds, others as greenhouse ornamentals, and the eggplant and red pepper are also of this genus.

The botanical divisions of plants require some explanation. Plants are grouped into large divisions known as *families*. Each family contains all those plants having a certain number of characteristics in common. For example, the nightshade family, *Solanaceæ*, includes all plants having the following characteristics: Herbs or shrubs with colorless juice, and alternate leaves without stipules. Flowers regular with parts in fives. Corolla with parts overlapping or touching by contiguous edges in the bud. Ovary usually 2-celled. Style single. Fruit a many seeded berry or capsule. Foliage strongly scented. Fruits often poisonous, but some are edible.

Families are again divided into groups called *genera*. For example, the genus *Solanum* includes those plants in the nightshade family having the following characteristics among others: Corolla wheel-shaped, 5-parted or cleft. Stamens with short filaments and long anthers, which often apparently unite around the style. Fruit usually a berry.

The genera are again divided into still smaller divisions called *species*. For example, the species name "tuberosum" refers to the potato, belonging to the genus "*Solanum*," of the *Solanaceæ*, and the botanist writes the name of the potato *Solanum tuberosum*, giving the genus name followed by the species name, capitalizing the genus name only (when the species name is that of a person or a country, it may be capitalized). Following are the characteristics of this species: A perennial with underground tubers by which it propagates itself asexually. Low-growing, much branched herbaceous tops. Leaves unequally pinnate. Flowers in clusters, variable in color—white, blue,

violet, purple. Fruit a berry but usually lacking in this country due to the deficiency of viable pollen. This species fruits abundantly in South America, where it is native.

6. The potato belongs to the nightshade family. Its botanical name is *Solanum tuberosum*. The resemblance between the potato and other nightshade plants is not obvious at first sight; but even a casual examination of their flowers and fruits reveals many similarities. There is difference as to size, to be sure; but in structure they resemble each other very closely. The fruits of all the nightshades are strikingly similar. The potato does not bear fruits very often; the pollen is usually not viable in North America. Occasionally, however, the green fruits may be seen on the potato vine. While not edible, they nevertheless are comparable with the tomato, both being seed-bearing berries. The fruits or berries of the potato are much larger than those of the common nightshade, but here again an examination of the structure of each will show how close is the resemblance between them.

7. Inter-grafting.—It is possible to graft a tomato on a potato, or a tomato on the common nightshade. Of course, the graft is of no commercial importance, and is of significance only in a scientific sense. But it illustrates in a graphic way the close relationship between the potato, the tomato, and the nightshade, all regarded by some authors as species of the genus *Solanum*.

8. Domestication.—All cultivated plants came originally from the wild, directly or indirectly. Some of them were brought under domestication so many centuries ago that there is no definite record of the date or process. Some, such as rice and the grape, were under the care of man before the advent of written history, and the early beginnings of domestication are, therefore, shrouded in the haze of the distant past.

We know, however, the broad outlines of the narrative, uncertain though its beginnings are; and we can pick out the different threads and follow each, step by step. We know

also that the story is not yet complete, but that even today the process of domestication and of plant improvement is going on.

There is a division of the Bureau of Plant Industry of the United States Department of Agriculture known as the Division of Foreign Plant and Seed Introduction, whose work it is to search for new and promising plants the world over. The interior of China, the wilds of Africa, the continent of South America have all yielded new forms to our list of cultivated plants. No corner of the globe is so inaccessible or so remote as to escape the vigilance of the explorers for new plant material.

9. American wild plants.—America has contributed many plants to the horticulture of the world. The origin of the Concord grape is narrated in a later chapter. The native plums, apples, and berries have been drawn on largely for new and better varieties and as yet the possibilities have not been exhausted. The conditions in America are different from those existing in the Old World; and plant forms are being developed to meet the needs of the continent.

THE PROCESS OF IMPROVEMENT

The question arises: Is plant improvement a matter of chance, or can it be controlled by man? Does nature work blindly to produce better forms, or may the intelligence of the skilled manipulator and student have an influence in it? Fortunately for the horticulturist, the work of plant improvement can be controlled and directed to a large degree by skill and study; and chance and "luck" play a part the importance of which is constantly diminishing as time goes on.

10. Darwin.—The studies of Charles Darwin mark the greatest contribution made in the nineteenth century to the subject of origins, and of variation in plants and animals. Darwin was born at Shrewsbury, England, February 12th, 1809. This same year marked the birth of two other great

characters of English history, Gladstone and Tennyson. Darwin's birthday, it will be noticed, is the same as that of Abraham Lincoln.

11. **The origin of species.**—Darwin was not alone in the discovery of the fact that the forms of plant and animal life are subject to variation; but he studied the matter so painstakingly, and wrote so convincingly, that his writings have profoundly influenced all scientific thought since his time. His great book, *The Origin of Species*, was published in 1859. In it he points out that the forms of life are constantly undergoing minute changes; that these changes may be so small at the time as to be scarcely perceptible, but that in the course of centuries they become sufficiently great to make the differences recognizable. For example, if a hundred seeds are planted from one parent plant, no two of these seedlings will be alike; and some will be better able to meet the conditions of life than will their fellows. They will tend to persist, and to transmit these differences to their offspring; and the other forms will tend to perish. The process is so slow as to escape observation; but in the course of many centuries the forms of plants and animals will gradually change. This, in essence, is Darwin's theory of evolution by means of natural selection. It is now recognized by scientific men everywhere as one of the fundamental hypotheses to account for the forms of life.

12. **Mendel.**—Gregor Johann Mendel, an Austrian monk, was born in 1822 and died sixty-two years later. He conducted experiments in the crossing of plants, publishing his results in 1865 in a paper under the title "Studies in Plant Hybridization." This paper attracted no attention in the scientific world when it was written, and subsequently remained unnoticed until 1900, sixteen years after the author's death. The discoverers of the paper recognized at once that it contained a fundamental law of heredity; and the researches of the obscure Austrian monk are now known to students of natural science everywhere.

13. **Mendel's law.**—Mendel worked with the ordinary garden pea. He noted that there are easily recognized differences in different varieties. The peas of some varieties are wrinkled, while others are smooth. Some flowers are purple, while others are red or white. The vine is dwarf in some varieties and tall in others.

He chose one set of contrasting characters and experimented with that. For example, he crossed a purple with a white-flowered variety. When the seed produced by this cross was planted, a vine with purple flowers resulted. But the plants of the generation following this hybridization did not all produce purple flowers. Indeed, one fourth of the plants of this second generation gave white flowers. The remaining three-fourths produced purple flowers. The white remained white through succeeding generations. One-third of the purple remained purple through succeeding generations. Two-thirds of the purple were indeterminate, breaking up in succeeding generations in the proportion of one-fourth pure white, one-fourth pure purple and one-half indeterminate. The following diagram (Fig. 1) shows how the purple color is controlling or dominant and the white not controlling or recessive, the numbers indicating proportions:

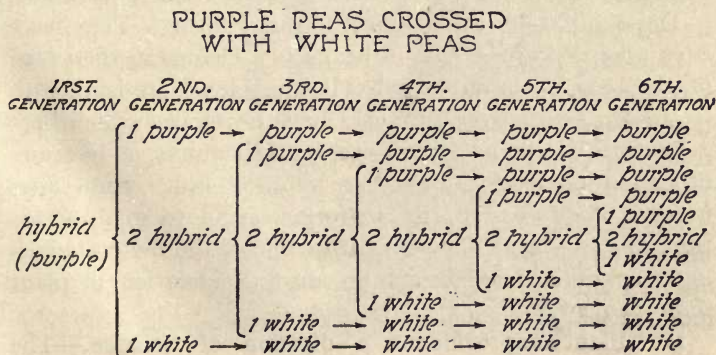


FIG. 1.—Showing how the purple color is dominant and the white recessive.

14. Dominant and recessive characters.—The white character in the above illustration disappeared in the first hybrid generation, and reappeared in succeeding generations. It is, therefore, said to be a *recessive* character, while the purple is spoken of as *dominant*. This behavior of characters is not confined to colors of blossoms of the pea. It is a fundamental consideration in all plant improvement through hybridization.

15. De Vries.—Hugo de Vries (born 1848), a Dutch botanist, was one of the discoverers in 1900 of Mendel's epoch-making treatise on hybridization. De Vries became professor of plant anatomy and physiology at the University of Amsterdam, in Holland, in 1878. His many important contributions to the study of plant-breeding have stimulated some of the most important investigations since Darwin.

16. The mutation theory.—With the name of de Vries is associated the "theory of mutation," first set forth by him in a book with that title in 1901. Darwin thought that changes are gradual, almost imperceptible, but that any change, no matter how slight, may give a plant an advantage which would enable it to survive in larger numbers than its less fortunate neighbors. De Vries proved by experimental evidence that sometimes changes occur, not gradually, but suddenly, or "by jumps." These changes are called *mutations*.

These mutations are manifest in many forms. They have been observed in the case of beans as a change in the shape of the seed or as an increase in the plant's resistance to frost. On peach trees, branches have developed which bore nectarines. In carnations and chrysanthemums, as in many other garden plants, sports are often found. Sometimes these mutations give rise to forms useful to man, sometimes the reverse. They constitute one of the factors which must be taken into account in any consideration of plant improvement.

17. Plant improvement a division of science.—The subject of plant improvement is so important that it is re-

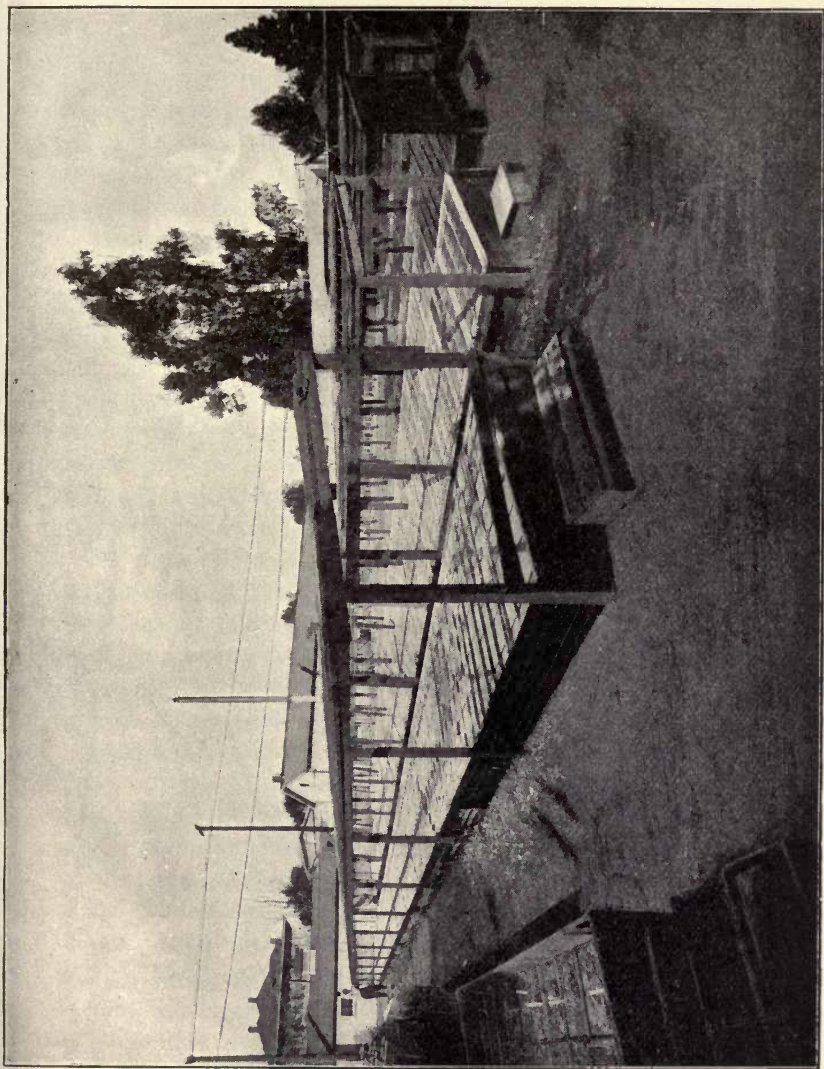


Plate I.—Propagating frames.

ceiving much attention. Throughout the country the experiment stations are working on the problem. They are conducting investigations with old varieties, in attempts to improve them; and they are working for new varieties, with the expectation of making contributions of value to growers. Nurserymen recognize the importance of the work. The researches of Mendel, de Vries, and others have indicated the path which the plant-breeder who is to achieve success must follow.

18. Hybridization.—When plants are crossed, new forms may result. The seed carries the characteristics of two parent plants, that which furnished the pollen, and that which bore the seed. The parents may have been unlike in one or more particulars, and the new seed may be dissimilar from either of them. The different characters may compose or blend in varying ways.

19. One effect of hybridization.—The crossing of plants has the effect of disturbing the type, with the result that new forms are likely to appear. These may be desirable to man, or of no importance. If desirable, the new form may be propagated at once by budding, grafting, cuttings, or other asexual means. If the plant is propagated by seed, the progeny must be selected, year after year, until the form comes true to type. This may require many generations of plants and hundreds or even thousands of individuals. The process is slow, laborious, and expensive; but it is one of the essentials in good plant-breeding.

20. Bud-selection.—The method of plant improvement known as bud-selection has received much attention in recent years. The term indicates the process of choosing buds for propagation from trees of known character. Its effectiveness in the case of all varieties of fruits is a matter of question at present. Results with apples, for example, have been both negative and positive. Other fruits, such as the Washington Navel orange, are much more given to the formation of bud

mutations, and bud-selection is useful not alone for the purpose of perpetuating more desirable forms, but also of avoiding the use of those that are less desirable. It is supposed to be specially efficacious in promoting productivity.

21. Ways in which plants vary.—Sometimes plants may be made to vary with regard to chemical contents of root, stem, leaf, or fruit. An excellent example is afforded by the sugar-beet, which, in the course of twenty-five years, was so changed by breeding and selection that the average sugar-content was raised from 6 to 15 per cent, and in exceptional cases, as high as 22 or 23 per cent. Another example of such variation is the changing of the proportion of protein to starch in Indian corn. In the corn used for the manufacture of corn-starch, the starch-content of the grain has been increased materially, and the protein-content decreased. Still another example is the increase in the proportion of sugar in plums; the prune is a plum in all respects except that it has sufficient sugar to enable it to be dried without removing the pit. This addition of sugar has been secured by means of selection with regard to sugar-content through a long period of years. Plants may be improved in respect to the size of their fruits. The wild crab is very small in comparison with the cultivated apple. Varieties of blackberries produce fruits differing greatly in size. The same is true of the tomato and many other cultivated plants.

Again, plants may be made to change with respect to their resistance to frost and the time of ripening of the fruits. Bailey states that apples not suited to our northern climate have been changed by crossing with Siberian crab-apples so that the area adapted to apple-growing has been extended northward. The peach is particularly susceptible to frost-injury; yet it is grown successfully today on both the American and Canadian side of the Great Lakes, as well as in Nova Scotia. This is largely the result of the securing of varieties

better adapted to the rigors or the shorter seasons of these northern localities.

22. Life forms not fixed.—In many other ways plants are varying constantly. It must ever be borne in mind that the forms of life are not fixed, that all forms are to a certain degree plastic, and that within certain limits they can be changed by the efforts of skilled manipulators. The improvement of plants is one of the great and interesting problems of horticulture.

23. Modern conditions demand the best.—A merchant must have on his shelves an up-to-date stock if he is to compete on successful terms with progressive rivals. A railroad company must look to the condition of its engines and cars and buildings. The horticulturist is also a business man, and his stock in trade is the plants he cultivates. He will take risks, as does every other business man. He will have disease to combat, and insect pests to control, irrigation questions to solve, and problems of every sort to face. Competition has always been keen, and is keen today. It is essential, therefore, that his stock be up-to-date, that his trees and plants represent the best that can possibly be secured.

24. The goal.—The possibilities of plant improvement are so great that no matter how much has been accomplished or how much may yet be undertaken, the goal will always be ahead. There is plenty of room for achievement. Plant improvement is of vast importance to the human race. To the individual horticulturist and the scientist, it opens an inspiring field for his endeavor.

The elements in practical plant-breeding are these: (1) to produce or discover a desirable variation; (2) to stabilize and perhaps to improve the variation by continued selection. The operator should understand the laws of heredity, that he may know what is possible of accomplishment and thereby direct his effort intelligently.

EXERCISES

EXERCISE I.—Wild and domesticated forms.

Materials.—Mature specimens of the following plants showing roots, stems, leaves, flowers, and fruit: Tomato, potato, nightshade.

Procedure.—Note the general appearance of these different plants. Does a superficial examination reveal any similarities? Compare closely the leaf of the potato with that of the tomato and the nightshade. Point out all the similarities and all the differences that you can detect. Do the same with the flowers of the three plants, examining the structure of the flowers in some detail. Count the sepals, petals, and stamens of each. Note the form of the corolla in each case. Does this suggest any relationship existing between the different plants?

It may be difficult to find a potato fruit, but if possible secure one and compare it with the fruit of the tomato and of the nightshade. What evidence is there here of similarity of structure? Why is it that the potato is grown for its tubers while the tomato is grown for its fruit? The structure shows that they have a close botanical relationship. The potato and tomato are indigenous to the Americas, while some form of the nightshade is found in widely separated parts of the world. A study of the history of the tomato shows that a hundred years ago it was regarded as poisonous and this prejudice against it disappeared only recently. The present cultivated forms are also a very recent development.

Do you think it would be possible to make such improvements in the nightshade as have been brought about in the tomato? Explain fully the reasons which lead you to your conclusion.

Why does the potato not bear fruit as does the tomato? Do you think it would ever be possible to secure a potato which would bear fruit regularly? If so, how could this be accomplished? Would there be any advantage in having such a potato?

EXERCISE II.

Materials.—Wild forms native to the student's locality.

Procedure.—Bring to class samples, including, if possible, fruit of any plants growing wild in your locality which are closely related to cultivated forms. For example: In many parts of the United States there can be found wild cherries, plums, grapes, strawberries, crab-apples, or other plants. Are these specimens which you have brought truly wild or are they feral? Explain the difference between the two terms. Are these specimens superior in any way to the cultivated forms? (In answering this question think of their resistance to disease,

their tendency toward fruitfulness, their flavor, size, resistance to insect pests, susceptibility to frost).

If in a region where members of the huckleberry, cranberry, or blueberry family are found bring in specimens of these plants. Do you consider them wild or domesticated? Where did they originate? Is there any possibility of improvement in the future? If so, along what lines?

EXERCISE III.—Project study.

Procedure.—The student should report in class concerning the type of project which he plans to take up during the school year. He should also discuss at this time the connection between plant improvement and the crop that he is growing. If it is an annual, he should take up the matter of seed selection and should get all the information he can from books or from publications of experiment stations concerning the work that has been done with his individual crop. If he has old trees, he should know the variety and should ascertain, if possible, the probable origin of this variety and its desirability as a commercial product.

CHAPTER II

THE LIVING PLANT

PLANTS, like animals, possess the power to grow and to reproduce. Several interesting ways of reproduction are discussed in the chapter on plant propagation. It is also of value to the horticulturist to know something of the structure of plants and their life processes. The more knowledge he possesses of the living plant, the greater is his power to make it serve his purposes.

25. Parts of plants.—A very casual observation will show that the roots, stems, leaves, flowers, and fruits are the main parts of our common plants. The plant parts are made up of tissues consisting of cells. The cell is the unit of plant structure.

26. The cell.—Robert Hooke in 1667, while examining the bark of the cork-oak with a microscope, noticed very small structures which looked like the cells of honeycomb. He called these plant-cells. Although most plant-cells are not shaped like those in honeycomb, the name given by Hooke is still applied to them, no matter what their shapes may be.

27. Number of cells necessary to plant life.—In some cases, single cells can live independently. Such a cell performs all the functions necessary to life, including reproduction. The so-called "higher" plants, which include most of the cultivated kinds, are made up of a number of cells, and are, therefore, said to be multicellular. The number of cells in a plant may be very large, amounting to thousands or even

millions. They are of various sizes and shapes (Fig. 2), and are modified to perform definite functions.

28. Structure of plant-cells.—A section of a living cell is shown in Fig. 3. The cell-wall surrounds a mass within, largely made up of a living substance called protoplasm. Protoplasm enters into the composition of a body within the cell known as the nucleus. The part of the protoplasm between the nucleus and the cell-wall is known as cytoplasm. In the

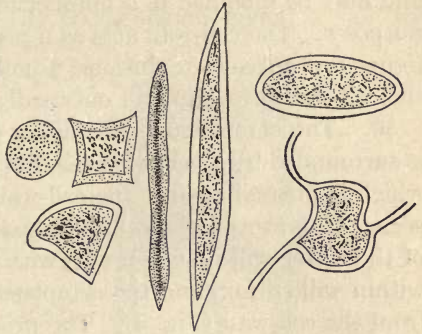


FIG. 2.—Plant-cells of various shapes.

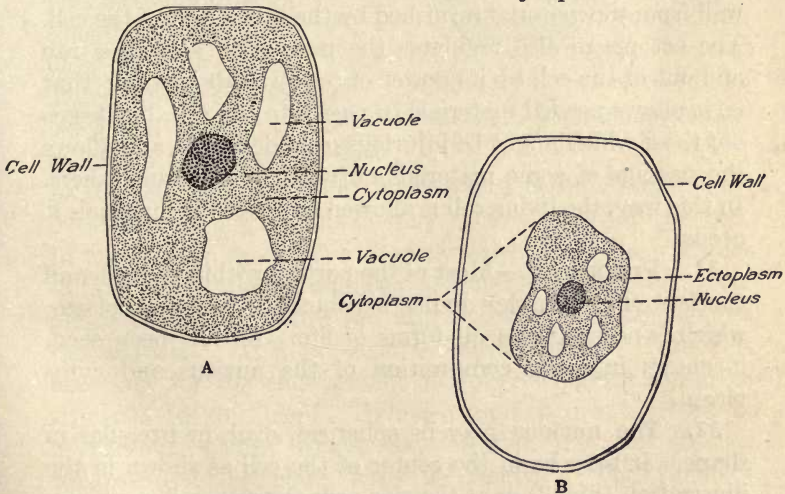


FIG. 3.—A, Diagram of a cell. B, A plasmolyzed cell. The protoplasm has shrunk to an irregular mass.

cytoplasm may be found vacuoles, granules, plastids, and crystals.

29. The cell-wall (Fig. 3) is non-living, but was built up by the living part of the cell. It varies in composition and may be modified in a number of ways to serve different purposes. The cell-wall acts as a protective covering for the living protoplasm. Solutions usually pass readily through the cell-wall inwardly and outwardly.

30. The ectoplasm.—The living part within the cell-wall is surrounded by a very thin membrane called the ectoplasm, which is pressed against the cell-wall so that it is not easily seen. If, however, the cell is placed in a salt solution, some of the water will be taken out, with the result that the part within will shrink, and the ectoplasm will become separated from the cell-wall (Fig. 3). The process of shrinkage in this manner is called plasmolysis. The ectoplasm serves to give the young cell support before the cell-wall is formed, and together with the nucleus controls the building of the cell-wall from the material furnished by the living part of the cell. The ectoplasm also regulates the passage of solutions into and out of the cell by its power of selective absorption; that is, it allows needed materials to pass into the cell, but keeps out those which might be injurious or undesirable, and allows the passage of some materials outward, but retains others. In this way, the living cell is allowed to select the materials it needs.

31. Protoplasm.—Most of the portion within the cell-wall consists of a complex living substance called protoplasm, which is necessary to all forms of life. As has been seen, it enters into the composition of the nucleus and cytoplasm.

32. The nucleus may be spherical, oval, or irregular in shape. It may be in the center of the cell as shown in the illustration (Fig. 3) or at the side near the cell-wall, or in any other part. It is usually found near the portion of the cell which is growing most actively. The nucleus is necessary to the life of the cell and plays a very important part in its

reproduction. One of the common ways in which it aids reproduction is through division, whereby two cells are developed from the original one.

33. Cytoplasm (Fig. 3) is the name given to all the protoplasm within the cell-wall, with the exception of the nucleus. Together with the nucleus, it carries on the activities of the cell. It contains vacuoles, granules, plastids, and crystals.

34. Vacuoles.—In the cytoplasm occur what frequently appear in young growing cells to be small globules of clear liquid. These are called vacuoles and the liquid is known as cell-sap.

As the cell becomes older, the vacuoles become larger until frequently a single vacuole may occupy most of the cell. In the cell-sap are acids and salts which cause the vacuoles to take up and hold a quantity of water, enabling the protoplasm to fill the entire cell and to exert pressure against the cell-wall. This pressure is called turgor. Turgor is necessary for the enlargement of the growing cell and gives strength to the plant. When turgor is wanting, as in herbaceous plants which have wilted, the soft tissues collapse and the plant loses its rigidity. The vacuoles store manufactured food materials until they are needed by the cell. They contain also excretory products which the protoplasm cannot use.

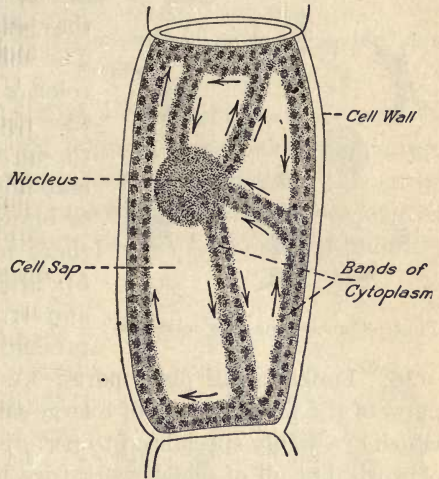


FIG. 4.—Cell showing circulation of the cytoplasm (streaming). Arrows show direction of movements.

35. Plastids are small bodies contained within the cytoplasm. They possess the power of growth and multiplication by division. There are three types. The leucoplasts are colorless. Their function is to change soluble sugars into

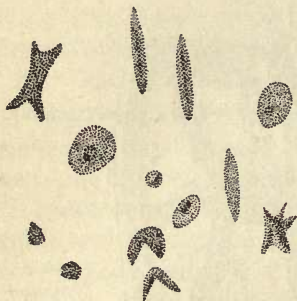


FIG. 5.—Chromoplasts of various shapes.

insoluble starch grains which they store within themselves. The chloroplasts are green in color and are necessary in the manufacture (photosynthesis) of plant-food. The chromoplasts are red, yellow, or orange in color and sometimes crystalline in form (Fig. 5). The colors of many flowers and fruits are due to their presence.

36. Functions of plant parts.—As has been stated, the parts of the plant consist of a large number of cells, many of which are highly specialized to perform certain definite kinds of work, but all of which work together for the good of the plant. Each part of the plant performs certain functions. For the convenience of the student, the uses of the roots, stems, leaves, flowers, and fruits are summarized in the following:

FUNCTIONS OF PLANT PARTS

- | | | |
|----------------------|---|--|
| I. The Roots . . . | { | <ol style="list-style-type: none"> 1. Absorb water and food materials. 2. Transport water and food materials. 3. Store food material. 4. Fix the plant in a definite place and position. |
| II. The Stem | { | <ol style="list-style-type: none"> 1. Transports water and food materials. 2. Holds the leaves up into the sunshine and air. 3. Stores food material in many cases. |

- | | | |
|------------------------|---|--|
| III. The Leaves . . . | $\left\{ \begin{array}{l} 1. \text{ Manufacture food material for use in the plant.} \\ 2. \text{ Respire.} \\ 3. \text{ Transpire.} \\ 4. \text{ Shade the stem.} \end{array} \right.$ | |
| IV. Flowers and Fruits | | |
| | | $\left\{ \begin{array}{l} 1. \text{ Form seeds in order to produce new plants.} \end{array} \right.$ |
| | | |

37. Roots (Figs. 6 and 7).—As to shape, roots may be placed in three classes: (1) Tap-roots are thick and tapering. Such roots may be several inches in length, as in the carrot and the beet, or may be a number of feet long, as in the walnut and pecan. (2) Fascicled roots are



FIG. 6.—Tap-root of carrot.

thick and fleshy, but somewhat irregular in shape, as in the sweet potato. (3) Fibrous roots are long, slender, and more or less crooked. Such roots spring from tap-roots and fascicled roots, or are found on plants having neither tap- nor fascicled roots.



FIG. 7.—Fascicled roots of the sweet potato.

38. Manner of growth of roots.—As the plant grows, the roots increase in length by the multiplication and enlargement of cells near the tip. As a root pushes through the soil, it is protected by a root-cap consisting of a number of modified cells (Fig. 8). Branch roots arise from older roots in a different manner than do the branches of stems. The branch (lateral) roots grow out from the central interior portion of older roots, while the lateral branches of stems arise from buds formed by the outer tissue of the stem.

39. Functions of roots.—Plants depend on the roots for the absorption from the soil of water and substances in solution to be manufactured by certain cells into food material.

The main part of the root does not absorb such material, but the absorption is by specialized cells known as root-hairs (Fig. 9). A root-hair is a single, elongated, living cell, consisting of the usual parts of the cell

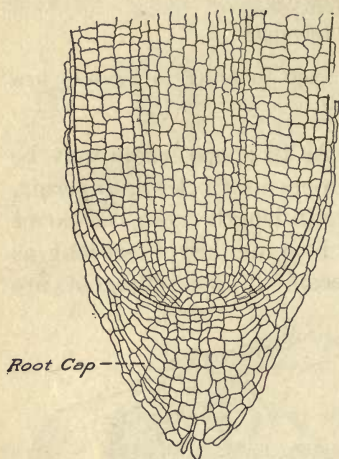


FIG. 8.—Tip of root showing root-cap.



FIG. 9.—Root-hairs on young radish.

(Fig. 10). Root-hairs are produced by the outside (epidermal) tissue of the root, and occur near the growing point of the root. If plants are dug up carefully and the soil washed from the small fibrous roots, the root-hairs can be seen readily. The root-hairs are short-lived and are found only on the young roots near the tips. As the roots get older, the root-hairs farthest back gradually die and are replaced by those growing near the tip.

The root-hairs absorb solutions from the soil by osmosis. The process of osmosis can easily be illustrated artificially by an old experiment. A thistle-tube is filled with molasses or sugar solution, and a membrane such as a pig's bladder or parchment paper is tied across the large end. The tube is then inserted in a beaker of water with the large end down so that the membrane is submerged in water. A rise of liquid in the tube shows that the dilute solution is passing through the membrane into the denser sugar or molasses solution.

The dense solution also passes through the membrane into the weaker solution as can be noticed by the sweet taste of the water in the beaker, but most of the passage is from the weaker to the stronger concentrated solution. The passage of solutions of different densities through semi-permeable membranes into other solutions in this way is known as osmosis. The root-hairs are able to take up water and substances in solution because the cell-sap is of greater concentration than the solutions in the soil. But if the solutions in the soil should become stronger than the cell-sap in the root-hairs, the cell-sap would move outward into the soil solutions, and injury or death to the plant would be the final result. This is one reason why plants cannot grow in soils strongly alkaline.

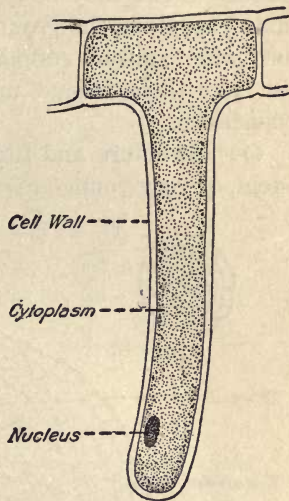


FIG. 10—Root-hair magnified.

Before the salts taken up by root-hairs can be used by the plant, they must be transported through the roots and stem to the leaves where they are manufactured into plant-foods. It is important to understand that the older roots do not absorb solutions, but carry them.

Roots also serve as storehouses for food materials, most of which are in the form of starches. Thick fleshy roots possess a large amount of stored food. Plants living two years (biennials) usually do not produce seed the first year, but manufacture and store up food in the roots. The stored food is used the second year to aid in producing the top of the plant, and the thick roots shrivel. The plant produces seed the second year and then dies, root and top. Carrots, parsnips, and the like, are examples.

40. The stem.—Many kinds of stems are common to plants. Some are herbaceous and consist almost entirely of living tissue; others are woody and consist largely of dead tissue. Stems may be long or short, slender or thick. They may run along the ground as in many vines, or may climb or twine around supports, or may be of such strength as to hold their foliage up into the air and light without assistance.

41. Structure and functions of the stem.—In the young stem, or very young growing portions of older stems, the cells

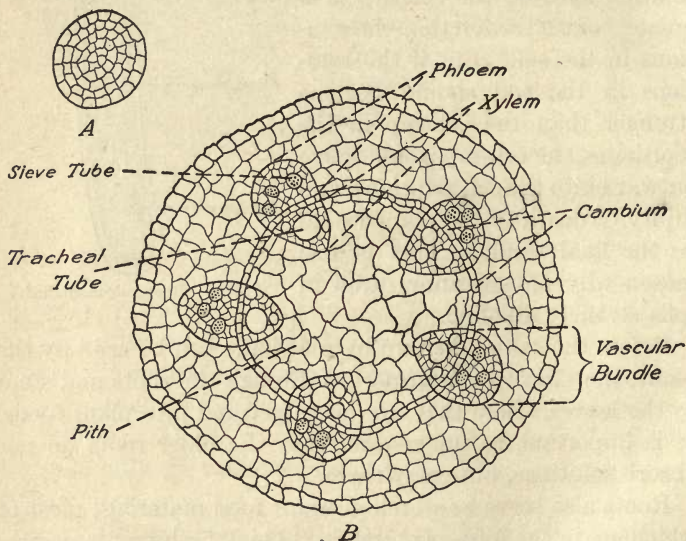


FIG. 11.—A, Cross-section of very young growing portion of exogenous stem with cells nearly alike. B, An older stem with various tissues developing.

are much alike. Later they become differentiated. Figs. 11 and 12 show the appearance in cross-section of a number of bundles (vascular bundles) in the pith of a stem. The inner side of each bundle consists of various modified cells which later form the woody portion of the plant known as the xylem.

The outer portion of each bundle also consists of modified cells and is known as the phloem, or true bark. Between the phloem and the xylem is a thin tissue of cells known as the cambium. It will also be seen that the cambium extends in a circle through the pith. The cambium cells are the growing portions and build up the other parts of the stem. It is through the vascular bundles that solutions travel upward and downward through the tree. The solutions travel upward almost entirely through the xylem and downward

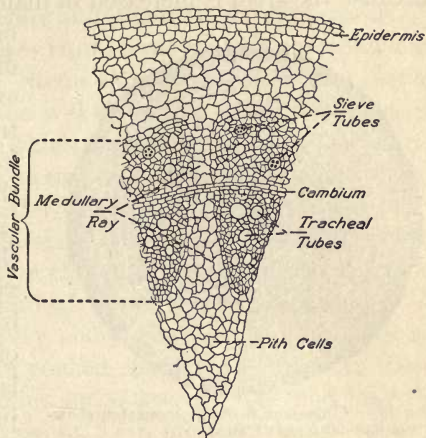


FIG. 12.—A section of same stem as in Fig. 11, older, with vascular bundles closer together and pith between compressed into medullary rays.

through the phloem. Specially modified cells, called tracheal tubes, occur in the xylem for the passage of solutions upward. Other modified cells, known as sieve-tubes, are present in the phloem for the passage of the solutions downward. Both of these types of cells carry solutions after the cells are dead. They are illustrated in Fig. 12. These are not the only types of cells in the vascular bundles. It should be noticed also that, although most of the movement of solutions through the stem is upward and downward, some movement takes place in other directions.

As the stem becomes older, the vascular bundles press the pith between them into thin plates called medullary rays. In old stems the xylem forms a continuous ring of wood and the phloem a continuous ring of bark with the cambium between the wood and bark. Each growing season the cam-

bium forms a layer of bark inside the old bark. As a ring of wood is added every growing season, the age of a section of a stem can be told approximately by counting the rings. Because the stem is increased in diameter by layers of wood

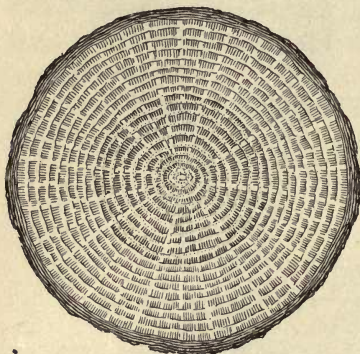


FIG. 13.—Cross-section of exogenous stem showing annular rings of wood.

on the outside, this type of stem is said to be exogenous (Fig. 13). Most trees are exogens. It is important to remember that in exogenous stems, the solutions pass upward through the wood or xylem inside the cambium layer, while most of the passage downward is in the bark or phloem just outside of the cambium layer.

Another type of stem is that in which the vascular bundles are not arranged in circles but are scattered throughout the stem (Fig. 14). Each vascular bundle is similar in structure to

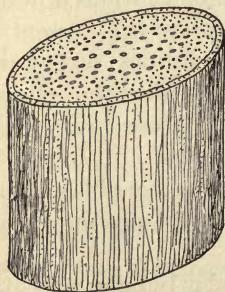


FIG. 14.—Cross-section of endogenous stem showing scattered arrangement of vascular bundles.

those already mentioned and the solutions pass through them in the same way, but rings of wood are never formed. Because the growth takes place on the inside, such plants are called endogens, and include palms, corn, and all true grasses.

Stems store food materials for future use, usually in the forms of starches, which are insoluble. It should be remembered that food materials can be transported by the

plant only in soluble forms, such as sugars, but that they are changed into starches in order to be insoluble for storage.

Before stored food can be used by the plant, it must be changed again into soluble forms. By action of certain substances known as enzymes or ferments, plants are able to change starches to sugars and sugars to starches readily.

42. Growth of stems.—How stems grow in diameter has already been explained. Stems elongate from growing points or buds. An examination will show that there are nodes or joints at the points from which the leaves grow out. The parts between the nodes are designated internodes. The internodes do not elongate after the first growing season is past.

43. Buds.—Several kinds of buds are formed from certain tissues of the outer portion of stems. Buds may be classified according to function as leaf, flower, and mixed buds. A leaf-bud consists of a very short axis having internodes so short that the nodes are packed closely together. At these nodes are very small undeveloped leaves. The bud may be covered with protective scales, as in most perennials (plants which live for more than two years), or they may not have protective scales and are then said to be naked, as in many herbaceous plants. A leaf-bud is really a potential stem. It elongates into a stem and its leaves develop into the foliage. A flower-bud develops into flowers which under favorable conditions set fruit. The number of flowers differs in the various buds; for example, in the cherry the number is from three to five, in the plum two or three are common. Mixed buds contain both flowers and leaves, as in the apple.

Buds may be active, dormant, or adventitious. Active buds are those that grow under normal conditions. Dormant buds do not grow to any extent, but possess the power of growth should favorable conditions arise. As a rule, buds near the tip of twigs are more active than those at the base, many of which are dormant during the growing season. Of course, all buds are dormant in the winter in cold climates. Adventitious buds are not visible but arise from unusual conditions, such as injury.

As to position, buds may be terminal, on the tip of the stem; or lateral, on the side of the stem (Fig. 15). Lateral buds always originate in the axils of leaves, that is, in the angle where the leaf joins the stem. The leaves fall, finally, leaving scars, above which the buds can be seen. The ordinary active bud continues the growth the year following the dropping of the leaf in whose axil it was borne.



FIG. 15.—Twig showing terminal and lateral buds. A, terminal; B, lateral.

44. Fruit-buds.— Flower- or fruit-buds are formed from the same kind of tissue as are leaf-buds. Very early in their development it is difficult to tell which are flower- and which leaf-buds, even when microscopic sections are made. Later the differentiation is so marked that fruit-buds can be easily distinguished from leaf-buds with the microscope.

When well developed, the flower-buds can usually be identified by their plump appearance and by the fact that they stand out from the stem more than the leaf-buds and are not so sharp and pointed. In many cases, they may be distinguished from the leaf-buds by their arrangement or position on the stem. For example, many of the stone-fruits bear fruit-buds on the lateral (side) branches, where the buds occur at the nodes in threes, the middle one being a leaf-bud and the outer two fruit-buds (Fig. 16). The peach tree bears its fruit in this manner on wood formed in the previous season. This must be taken into account when pruning. It is necessary not



FIG. 16.—Peach twig showing habit of bearing. The buds are borne at the nodes in threes, the middle one being a leaf-bud and producing a stem bearing leaves; the two outer are fruit-buds.

only to thin out branches to admit light, but also to leave a proper amount of the lateral growth so distributed as to bear the crop in the best way.

Fruit-buds are sometimes borne on spurs. A spur is merely a very short condensed branch. Spurs may live to bear one crop only as in the almond, or may live for a few years as in the apricot, or may live for a long time as in the apple. In trees which bear fruit on spurs, it is very important in pruning to preserve the spurs. This is especially true of the apple and pear.

The following shows the way in which fruit-buds are borne on several kinds of trees:

SPECIES OF TREES	HOW FRUIT-BUDS ARE BORNE
Peach	On laterals
European plums	Mostly on spurs
Japanese plums	On spurs and on laterals
Almond	Mostly on spurs
Cherry	On spurs
Apricot	On spurs and on laterals
Apple	On spurs entirely, except in some of the western states where the ter- minal buds also frequently bear fruit
Pear	Same as for the apple

An apple spur does not bear fruits annually but only every other year (Fig. 17). If it bears a fruit on its terminal bud in 1922, it forms a leaf-bud on the side which continues the growth of the spur in 1923. In 1923 a fruit-bud is formed on the end of the spur which bears a fruit in 1924. Usually some of the spurs bear fruit one year and others the next, so that a crop is obtained every year, but many times all the spurs bear fruit the same year and not the next, in which case a crop is obtained every other year only. Some trees are more likely to have this habit of alternate bearing than others, but frequently unusual conditions are responsible for it. It is difficult to get trees out of the habit when once it is estab-

lished. It is possible that at some future time methods of pruning, culture, and irrigation may be devised which will overcome alternate bearing in fruit-trees.

45. The leaves.—Leaves generally have two parts, the blade and the stalk (petiole). Sometimes smaller leaf-like structures, called stipules, are borne at the base of the petiole, as in the leaves of many varieties of apples. When leaves have no petioles, they are said to be sessile. When

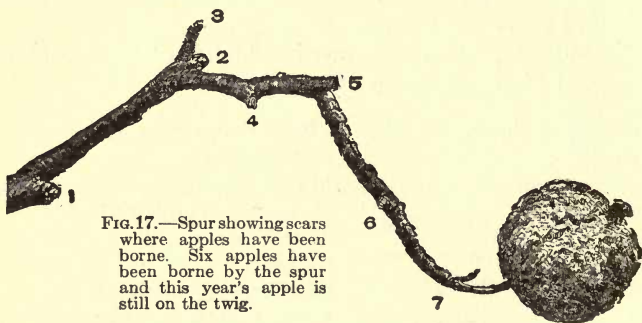


FIG. 17.—Spur showing scars where apples have been borne. Six apples have been borne by the spur and this year's apple is still on the twig.

the blade of a leaf is single, it is simple as in the plum or cherry, and when the blade is divided into a number of small leaves, as in the carrot, it is compound. Leaves may be parallel-veined as in the grasses, or netted-veined as in the apple or peach. Netted-veined leaves grow on exogenous stems, and parallel-veined leaves on endogenous stems. Leaves vary greatly in size, shape, thickness, and markings.

46. Structure of leaves.—Vascular bundles run up from the stem through the petiole and into the tissues of the blade of the leaf, subdividing and becoming smaller until they end in a few rows of cells. The vascular bundles carry water and food material in solution to and fro, and also strengthen the leaves.

The structure of a leaf is best shown by a cross-section diagram. The upper and lower surfaces of the leaves are covered

by a single layer of cells known as the epidermis (Fig. 18). In the epidermis are small openings called the stomata.¹ Each stoma lies between two modified cells, called guard-cells.

These open and close, thus regulating the size of the stoma. Underneath the upper epidermis are one or more layers of cells, which, because of their long shape, are termed palisade-cells. These contain chloroplasts and chlorophyll,

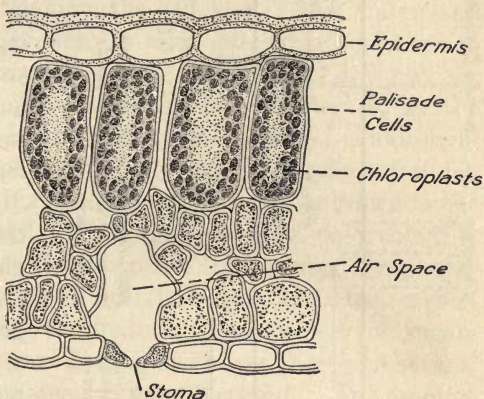


FIG. 18.—Portion of a cross-section of a leaf showing different cells.

a green colored substance. Beneath the palisade-cells are irregular-shaped thin-walled cells (parenchyma cells) and between them are air spaces (intercellular spaces).

47. The functions of leaves (Fig. 19).—Leaves are very important plant organs. One function is that of transpiration, or the “giving off” of water in the form of vapor. Leaves give off moisture for two reasons. In the first place, transpiration regulates the temperature of the plant. Secondly, the plant takes up more water than it can use in order to obtain the necessary amount of soluble food materials. It must get rid of the surplus water, which it does through the little openings (stomata) in the epidermis of the leaves. The guard-cells resemble in shape the halves of a doughnut. When there is plenty of moisture, the guard-cells are full of water and are turgid so that between them there is a wide opening. If for any reason moisture is lacking in the plant, transpiration

¹ Singular—stoma.

is lessened by the guard-cells shrinking together and leaving a smaller opening. The quantity of water transpired by

plants is very great, in many species being equivalent in a season to several hundred times the weight of dry matter in the plant.

The second function of leaves is respiration, in which the leaves take in and give off the same kind of gases as do human beings when they breathe. Leaves respire more or less all the time, both day and night. In respiration, oxygen is taken in from the air and carbon dioxide is given off. The purpose of respiration is to supply energy.

The most important function of the leaves is photosynthesis, or the manufacturing of food material by the aid of light. As light is necessary for photosynthesis, the plants

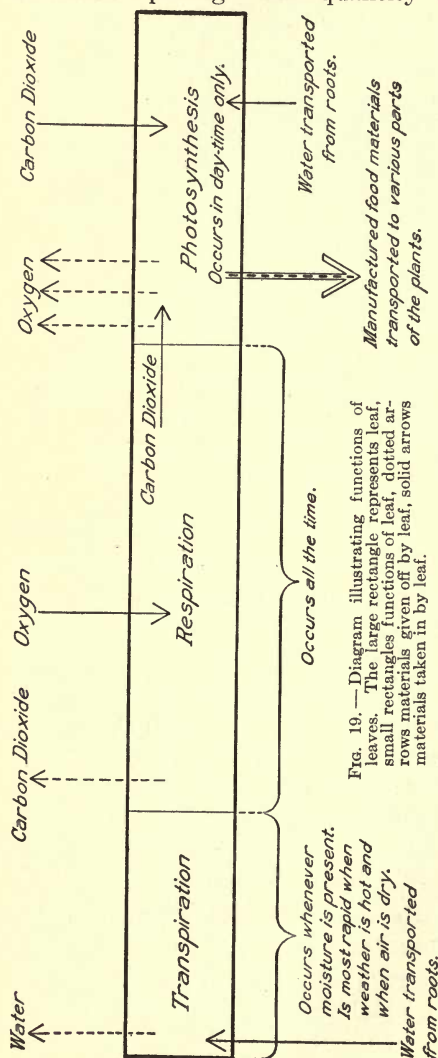


FIG. 19. — Diagram illustrating functions of leaves. The large rectangle represents leaf, small rectangles functions of leaf, dotted arrows materials given off by leaf, solid arrows materials taken in by leaf.

manufacture food materials in the daytime only. Briefly the process is as follows: Water is taken up by the root-hairs and transported to the leaves. Carbon dioxide in the air is taken in by the leaves through the stomata. The water and carbon dioxide are broken up and united in the leaves to form sugars, and oxygen, a waste product of the process, is given off. The process takes place extensively in the palisade-cells of the leaves through the action of chlorophyll, a greenish-colored oily liquid, for the production of which light is necessary. It is well known that plants grown in the dark lack chlorophyll. This explains their pale coloring. It will be seen that light supplies the energy for photosynthesis, that chlorophyll does the work, and that carbon dioxide and water are the materials from which the sugars are made. The process is complicated as there are several chemical steps before sugar is manufactured.¹ The amount of sugar manufactured is considerable but varies with different plants. Other forms of sugar, as well as grape sugar, are found in the plant. Protein materials also are manufactured by plants, and certain fats and oils. The manufactured carbohydrate food material is transported to the different parts of the plant in the form of sugars, which are soluble, and is stored in the form of starches, which are insoluble.

It will be seen that the chemical process in photosynthesis is the opposite of that in respiration, and also that the materials used and waste products in photosynthesis are different than in respiration. It should be remembered that in respiration, oxygen (O) is used, and carbon dioxide (CO_2) is given off day and night, while in photosynthesis, carbon dioxide (CO_2) is used and oxygen (O) is given off in the daytime only. During the night, when respiration only is taking place, a small quantity of carbon dioxide (CO_2) is given off

¹ The chemical reaction may be summed up, however, as follows: Carbon dioxide $6CO_2$ plus water ($6H_2O$) form grape sugar ($C_6H_{12}O_6$), and oxygen ($6O_2$) is a waste product.

by the plants, but in the daytime, when both respiration and photosynthesis are taking place, all the carbon dioxide liberated by respiration is used in photosynthesis and does not get back into the air. In addition, a large quantity of carbon dioxide is taken out of the atmosphere and a considerable quantity of oxygen is added to the air. On the whole, then, plants take carbon dioxide from the air and add oxygen to it.

It is of interest to note that the plant obtains hydrogen from the water in the soil taken up by the roots; that oxygen is secured from this source and from the air taken in by the leaves; that carbon is taken in by the leaves from the air; that nitrogen must be secured from the soil in the form of salts by all plants except the legumes which, by means of the bacteria living in nodules on the roots, are able to use the nitrogen of the air; and that phosphorus, potassium, magnesium, sodium, calcium, iron, chlorin, and sulfur must be taken from the soil in the form of salt compounds.

EXERCISES

EXERCISE I.—Exercises in plant structure.

1. Materials.—Various plants with their roots.

Procedure.—Classify the plants according to their root systems into those possessing the following: (a) fibrous roots, (b) tap-roots, (c) fascicled roots. Arrange your results in the form of a table.

2. Materials.—Plants; shrubs; small trees with their roots.

Procedure.—Dig up carefully various plants and if possible small trees. Examine them for root-hairs. Notice especially their number and where they are borne.

3. Materials.—Exogenous and endogenous stems; microscope.

Procedure.—(a) Examine longitudinal and cross-sections of exogenous stems. Study their general structure. Draw and label the parts. Make thin sections of young stems and examine them under a microscope for cells of various shapes. (b) Examine longitudinal and cross-sections of endogenous stems.

4. Materials.—Leaves; microscope.

Procedure.—Place a piece of thin leaf under a microscope. Examine. In some leaves the cells can be seen distinctly, and in most leaves the green chlorophyll granules can be seen.

5. Materials.—Geranium or other leaves; microscope, glass slides.

Procedure.—Strip off a portion of the epidermis of a leaf, mount it in water on a slide and examine it under a microscope for a view of the stomata. Notice the guard-cells. Make an enlarged drawing of the surface view of a stoma. Where do you find the most stomata, on the upper or lower surface of the leaves examined? Account for this fact.

6. Materials.—Various kinds of plants and trees.

Procedure.—Examine the leaves of a number of plants and trees. Classify them into the following: (a) simple and compound leaves; (b) netted-veined and parallel-veined leaves; (c) leaves with and without stipules; (d) which of the plants in the list examined would you expect to have endogenous stems and which exogenous?

7. Materials.—Trees of the apple, pear, apricot, plum, or others having fruit-spurs.

Procedure.—Study and draw different types of fruit-spurs. Compare the length of internodes on a spur with that on an ordinary branch. Are the leaves and buds arranged in the same way on a spur as on an ordinary branch? In what respects does a spur differ from an ordinary branch and in what respects is it similar?

8. Materials.—Various trees.

Procedure.—Study leaf-buds. Starting at the base of a bud, remove the bud-scales in order. Compare the arrangement of the scales on a bud with that of the leaves on a stem, and also compare the number of leaves on a stem with the number of scales on a bud. How does a bud differ from a stem?

9. Materials.—Trees just before or just at blossoming and leafing-out time in the spring.

Procedure.—Examine trees of various kinds for leaf-buds, flower-buds, and mixed buds. Keep a list of the types of buds found on the various trees.

EXERCISE II.—Exercises to determine the growing portions of plant parts.

1. Materials.—Water-proof ink; ruler; young growing pea, corn, or other plants.

Procedure.—With water-proof ink place marks one millimeter apart along a small rootlet, along the growing stem, and along the main rib of a leaf. In like manner mark the entire surface of a leaf in squares.

Examine the marked parts from time to time to see where the marks are farthest apart. Which are the most rapidly growing portions in each case?

2. Materials.—Trees with growing shoots; labels.

Procedure.—(a) As early in the growing season as possible, select and label a growing shoot on any convenient tree. Make a drawing of the shoot showing nodes and internodes. Measure the length of the internodes and record the results on your drawing. Repeat the measurements every two weeks. Report the results. (b) Proceed in the same way with a branch two years or more of age on the same tree. Do the internodes lengthen? (c) What bearing have the facts learned in this exercise on pruning and forcing the height of head of a young tree?

EXERCISE III.—Exercise to show the presence of water in plant tissues.

Materials.—Cans or evaporating dishes; small scales; leaves; twigs from a tree; oven.

Procedure.—(a) Weigh out some fresh leaves in cans or evaporating dishes. Record the weights. Dry the leaves in an oven for a number of hours, at a temperature of about 212 degrees F. Then weigh the leaves again. The difference in weight is due to the loss of water. Compute the percentage of water contained in the leaves. Compare your results with those of others in the class. (b) Repeat the experiment with young twigs cut into small pieces. Obtain the percentage of water.

EXERCISE IV.—Exercise to illustrate osmosis or the way in which root-hairs absorb moisture.

Materials.—Thistle-tube; stand and clamp for holding thistle-tube; parchment paper or pig's bladder; molasses or sugar solution; beaker of water.

Procedure.—Perform the experiment described in paragraph 39.

EXERCISE V.—Exercise to show that the epidermis prevents unnecessary evaporation of moisture.

Materials.—Geranium stems.

Procedure.—Divide the stems into two portions. After removing the leaves, peel the outer tissue (bark) from one portion. Weigh each portion separately. Place both portions in the sun and after a time weigh again. Note the difference in loss of moisture. (The same experiment may be done with fruits of the apple, pear, or orange.)

EXERCISE VI.—Exercises in plasmolysis and turgidity.

1. Explain and illustrate with drawings plasmolysis of a cell.

2. **Materials.**—Stems of various plants such as geranium, alfalfa, marguerite, grape, cactus, peach twig, olive or oleander twig, pine twig.

Procedure.—Allow the stems to wilt for various lengths of time and then place them in water. What is the cause of the wilting? To what extent is it possible to let the stems wilt and have them recover? Does wilting injure all plants to the same extent? What effect has wilting on cuttings or young trees to be planted?

EXERCISE VII.—Experiment illustrating the ascent of water in plants.

Materials.—Fresh growing stems of willow or orange; eosin solution.

Procedure.—Place the stem in dilute eosin solution with the cut end downward. After a time trace the upward path of the water by the red color. What part of the stem carries the water upward? What effect would the girdling of the bark of a tree have on the upward passage of water?

EXERCISE VIII.—Experiment to illustrate transpiration

Materials.—Two tumblers; cardboard; geranium or other leaf.

Procedure.—Nearly fill a tumbler with water. Punch a hole in the center of a piece of cardboard and put the petiole of a leaf through the hole. Place the cardboard on top of the tumbler so that one end of the petiole projects into the water. Place a dry tumbler inverted upon the cardboard so as to cover the blade of the leaf. Notice the drops of moisture that gather after a few hours on the inner surface of the upper tumbler. Where did this water come from? Through what part of the leaf must the water pass in order to get to the blade? At what points does the moisture get out of the leaf into the air?

EXERCISE IX.—Experiment to locate stomata.

Materials.—Twigs with their leaves; boiling water.

Procedure.—Heat some water to boiling and plunge the end of a twig into it. Notice the forming of gas bubbles at the stomata.

EXERCISE X.—Experiment to show that carbon dioxide is given off by plants.

Materials.—Leaves of clover, alfalfa, or other plants; small vial; lime-water; air-tight jar.

Procedure.—Put a small amount of water into a quart jar having a tight cover. Fill the jar half full of the leaves. Set a vial of lime-water in the jar. Fasten the cover and put the jar in a dark place for twenty-four hours. A scum on the surface of the lime-water indicates the presence of carbon dioxide. What process was stopped by putting the jar in the dark?

EXERCISE XI.—Experiment with chlorophyll.

Materials.—Test-tubes; water; alcohol; benzol; corks; leaves.

Procedure.—Place a leaf in a little water in a test-tube and boil. Pour in alcohol, and heat. The solution appears green and contains chlorophyll and other colored substances. To separate these pour in a little benzol. Shake thoroughly. Place a cork in the tube and let stand. The bluish green substance is chlorophyll; the other substances are yellow.

EXERCISE XII.—Exercise to show the presence of starch in leaves.

Materials.—Alcohol; leaves; tincture of iodine.

Procedure.—Extract the chlorophyll from a leaf with alcohol as in the preceding exercise. Mash the leaf from which the chlorophyll has been removed, and add to it a few drops of dilute tincture of iodine. A blue color indicates the presence of starch.

CHAPTER III

PROPAGATION BY SEEDS

PLANTS reproduce themselves (1) sexually by means either of seeds or sex-spores, or (2) asexually by buds or tissues capable of forming buds, or by vegetative spores. Some plants depend for propagating themselves on one of these methods only, while others multiply by both sexual and asexual means.

48. Sexual reproduction.—Two kinds of organs are involved in the sexual reproduction of plants; stamens and pistils. The stamens produce pollen-grains which fall on or are carried by insects or wind to the top (stigma) of the pistil. Under favorable conditions, the pollen-grain on the stigma produces a tube which grows down to the egg-chamber (ovary) at the bottom of the pistil. A certain nucleus descends the pollen-tube and unites with the egg-nucleus in the ovary. The egg is then said to be fertilized. As a result of this process, seed is formed.¹

49. Structure of the seed.—A seed consists of the following:

1. The embryo or rudimentary plant, which is capable under proper conditions of growing into the mature individual.
2. Cotyledons or seed-leaves (one, two, or in some cases more) which may or may not be a part of the embryo.
3. Food material stored either in the cotyledons or outside of them.
4. Protective coats or coverings.

¹The process is explained more completely in Chapter XII on pollination and fertilization.

An understanding of these parts can best be obtained by studying certain of the larger seeds under a magnifying glass. Before examination, the seeds should be boiled for fifteen or twenty minutes or soaked in water over night. Beans, peas, corn, and pumpkin seeds are especially convenient for study.

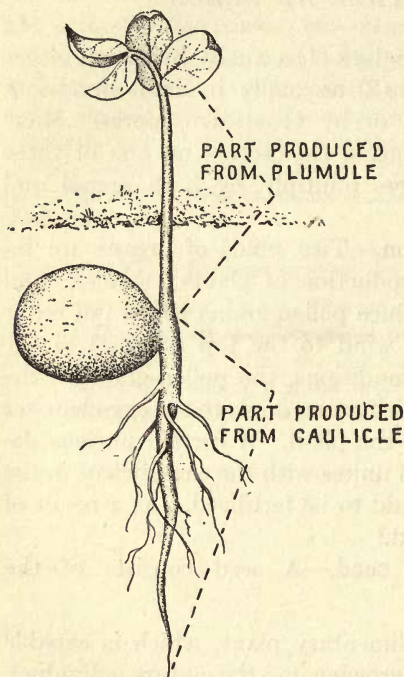


FIG. 20.—The young pea plant. Unlike the bean the cotyledons stay in the ground. Notice the plumule, and the roots developing from the caulicle.

50. The pea (Fig. 20).—Several marks are visible on the outer surface of the pea. A large scar, called the hilum, marks the point of attachment to the pod. At one side of the hilum is a little hole known as the micropyle. This is the point where the pollen-tube entered in the fertilization of the ovule. These marks belong to the coat of the seed, for if the coat (testa) is removed the marks come with it. The removal of the coat discloses two thick parts of the seed (cotyledons), commonly called the two halves of the pea. The cotyledons contain a large quantity of stored

food material on which the growing plantlet lives until it develops roots to take up nourishment from the soil and a foliage system to manufacture plant-food. Attached near its middle to the cotyledons is a little curved body (the embryo of the pea), of which one end (the caulicle) will

develop into the root system, and the other end (the plumule) will form the stem and foliage of the plant.

When the pea is planted, the cotyledons stay in the ground and, in supplying the young growing plant with food, they shrink and become wrinkled. The plumule pushes its way up through the soil to form the stem and leaves of the plant, while the caulicle grows downward, forming the root system.

51. The bean.—All the parts of the seed found in the pea are present in the bean (Fig. 21). The two little leaves in the plumule of the bean can be seen clearly with a small magnifying glass. The cotyledons, like those of the pea, contain an abundance of stored food material to supply the young plant until it becomes established. The growth of the bean, however, differs from that of the pea in several respects. The cotyledons of the bean do not stay in the

ground but are brought up on the stem into the air, where they turn green and function as leaves for a short time before they finally drop off. Some botanists consider that because the cotyledons function for a time as leaves, they are part of the embryo. Others think that they are not part of the embryo because they are not present on the fully developed plant. In the bean the plumule forms the part of the top above the cotyledons, while the caulicle forms both the root system and the part of the stem extending from the cotyledons to the roots.

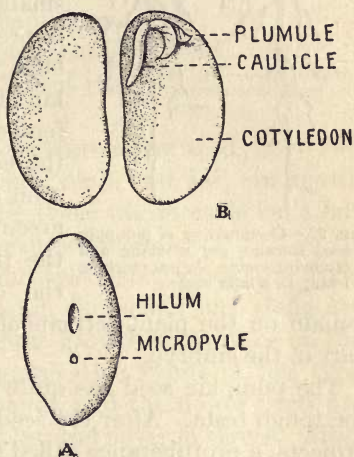


FIG. 21.—The bean seed. A, Exterior view of bean; B, two flat surfaces of bean after testa has been removed.

52. The pumpkin seed.—In the pumpkin seed, the testa (outer coat) is thick and hard, and when it is removed a thin

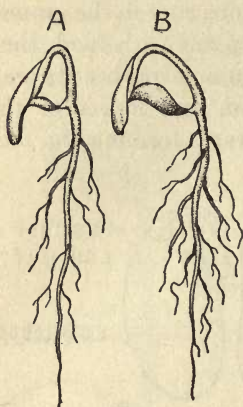


FIG. 22.—Germination of pumpkin seed showing peg catching and removing testa. A, peg catching testa; B, a later stage.

inner green coat may be seen. The cotyledons are thin, flat, and large. When the seed has been soaked, veins in the cotyledons show distinctly. The thin cotyledons of the pumpkin seed contain a much smaller amount of stored food than is present in those of the pea or bean; therefore, the young pumpkin plant must manufacture plant-food early. It does this by bringing the cotyledons up into the air as soon as possible, where they turn green and function as leaves while the true leaves are forming. As the cotyledons of the pumpkin

remain on the plant permanently and act as leaves, they are part of the embryo.

The pumpkin seed has quite a struggle to free itself from the tough testa. After the seed-coat cracks and the caulicle projects, a protuberance called the peg is developed at just the right place on the caulicle to catch hold of the split testa in such a manner as to pull it off the seed as the cotyledons are drawn upward (Fig. 22).

53. The corn.—Another type of seed is represented by the corn. The two sides of the kernel are illustrated in Fig. 23. One side is flat and smooth, while the other has a slight depression, lighter in color than the surrounding portions. Under this lies the embryo and the cotyledon. If a soaked

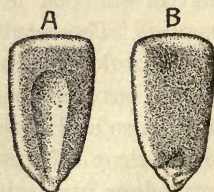


FIG. 23.—Exterior of the flat surfaces of a kernel of corn. A shows the slight depression under which lies the embryo; B, the opposite flat side.

kernel of corn is cut longitudinally the narrow way of the kernel so that a section similar to the one shown in Fig. 24 is obtained, the parts of the seed can be seen. The plumule and caulicle can be seen easily if the tip of each is raised with the point of a knife blade. Surrounding the plumule and caulicle is the cotyledon. The part of the seed to the left of the diagonal line in the illustration is not part of the cotyledon, but is stored food material for the use of the young growing plant.

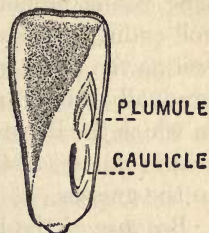


FIG. 24.—Longitudinal section of a kernel of corn.

54. Two classes of plants.—Plants whose seeds have two cotyledons, such as the pumpkin, bean, and pea, are known as dicotyledonous plants, while those whose seeds have one cotyledon are said to be monocotyledonous.

In the plants grown from dicotyledonous seeds, the wood fibers of the stems are arranged in circles and such stems are said to be exogenous, because the growth takes place on the outside as explained in paragraph 41. Plants of this type usually have netted-veined leaves, and the flower parts are in fives or fours or their multiples, and never in threes. Most of our fruit-trees belong to this class.

Plants grown from monocotyledonous seeds have endogenous stems with the wood fibers scattered through them as explained in paragraph 41. Such plants have parallel-veined leaves, and the flower parts are usually in threes or multiples of three. All true grasses belong to this type.

It will be seen that by studying the seeds, flowers, stems, and leaves, it is not only easy to place a plant in the correct class, but to foretell from the seed what kind of stem, leaves, or flowers the plant will be likely to have; or to tell, by examining the stem, leaves, or flowers, from what kind of seed any plant came.

55. How plants come up.—Each of these two groups of plants has its own method of coming up through the soil. The young monocotyledons have the leaves in a compact roll ending in a sharp point, which is forced up through the soil as the plant grows. After the leaves are through, they gradually unroll and spread out. On account of the manner in which the leaves come through the soil, monocotyledonous plants can get a start in very heavy compact soils, as is seen in the grasses.

Because of the large size of the leaves and the manner in which they are folded in the bud, dicotyledons cannot, as a



FIG. 25.—Bean coming through the ground, the cotyledons being pulled out. Notice crook in stem.

rule, successfully push their tops through the soil, especially in cases in which the cotyledons are brought out of the ground; therefore, the tops of such plants are pulled up by means of the stem (Fig. 25).

56. Seed dissemination.—Nature has provided for the distribution of seeds by various methods. Some seeds, as those of the thistle, milkweed, cottonwood, and dandelion, are provided with a downy covering or pappus which enables them to be carried long distances by the wind. Seeds of the maple, ash, elm, box-elder, linden, and many of the cone-bearing trees possess wing-like structures which enable them to sail through the air as they fall. Seeds which float easily, as acorns, nuts, and seeds of water plants, are transported readily by running water. Water from irrigation ditches frequently spreads weed seeds in this way. Many seeds have sticky coverings, or hooked appendages, which enable them to hold on to the wool and hair of animals. Beggar-ticks, stick-tights, and burdock seeds are examples. Some seeds are thrown explosively a number of feet, as in the mistletoe. Many pod-bearing plants, of which the touch-me-not is an example, throw their seeds by the contraction and curling up

of the halves of the pod. In the squirting cucumber, the least disturbance of the plant causes the cucumber to break loose from the stem and shoot its seeds with considerable force.

57. Rest-period of seeds.—In most cases, it would be fatal to the life cycle if seeds were to grow as soon as shed, because the young plants might be brought into growth at the wrong time of year and so subjected to frost-injury or to other unfavorable conditions. Nature guards against this by causing the seeds to go into a resting period as well as by requiring certain favorable external conditions before the seed can germinate. Many seeds remain in the resting period for a considerable length of time, others for a short time, while a few have no resting period at all.

58. Storage of seeds.—Man has learned to preserve seeds for certain lengths of time by providing them with conditions which will keep them in a resting state without injury.

Seeds with thin protective coats, including those of most of the vegetables and cereals, permit of air drying and can be preserved by storage in paper bags or boxes in a cool dry place. The temperature should remain as nearly uniform as possible, for if it varies, the growing power of the seed is likely to be impaired. The best temperature for storing seeds in temperate climates has been found to be between 60 and 70 degrees Fahrenheit, but there are exceptions; for example, Indian corn keeps best in a temperature near the freezing point.

Seeds with thick hard coats, such as nuts and pits of stone-fruits, keep best when stratified. Stratification consists in placing seed and sand in alternate layers in boxes (Fig. 26).

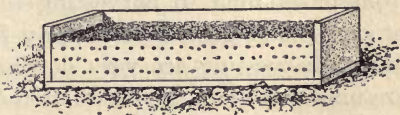


FIG. 26.—Stratification of seeds in box.

The sand should be kept slightly moist but not wet. It must be coarse enough to provide drainage, which should be facili-

tated by the boring of holes in the bottom of the box. The box should be covered with wire netting to keep out mice and other animals and buried with the top about four inches below the surface of the ground in well-drained soil, preferably on the shady side of a building. It is well to have the stratified seed exposed to weather action, for in cold climates frost and moisture crack the shell, and in warm climates warmth and moisture soften and split the shell so that at the proper time the seeds can sprout. Some nurserymen stratify large quantities of seeds in pits. The principle is the same as when boxes are used. Apple and pear seeds and others of a similar nature should not be allowed to dry out, but should be stratified as soon as freed from the pulp. Apple and pear seed are frequently stored and shipped in powdered charcoal. They should be kept in a cool place, an ice-house being very suitable.

59. Germination of seeds.—For the germination or sprouting of the seeds, it is necessary that they be viable, and that certain favorable external conditions be present.

60. Viability.—When a seed possesses the power to grow under proper conditions into a mature plant, it is said to be viable. A number of factors affect the viability of seeds, such as the maturity of the seed, climatic conditions, age of the seed, methods of storing, and mechanical injury.

It is necessary that the seed be mature. Immature seeds lose their viability quickly when stored, and should they germinate, the resulting plants are likely to be weak and to succumb readily to disease.

Seasons or climates in which the weather is fairly uniform from blossoming to harvesting time are favorable for the production of good seed. Early fall frosts or wet weather during harvesting are very detrimental. Tropical climates are unfavorable to the production of good seed.

The viability of seed is affected by age. This is due to the fact that during the normal resting period of seeds, certain physiological processes go on. These life processes are slight,

but are present nevertheless. After a time, however, a point is reached where the life processes cease, and the cells of the embryo lose their power to grow and multiply even when placed under favorable conditions. The length of time seeds retain their viability varies with the kind of seeds as well as with the conditions under which they are matured and stored.

Mechanical injury received in threshing, or due to the eating of parts of the seed by insects, may result in inability of the seeds to germinate.

61. External conditions.—The presence of moisture, warmth, and oxygen are the external requirements for the germination of seeds.

62. Moisture.—The first process in germination is the absorption of the proper amount of water. The presence of moisture is necessary because food materials can be transferred from part to part only when in solution. The water renders possible the action of enzymes (ferments) always present in the seed. By action of the enzymes, the stored food material is converted into the forms needed for the growth of the embryo. While the amount of water most suitable for germination varies with different seeds, usually enough should be present to keep the seed saturated, but not enough to exclude the air.

63. Oxygen is necessary for the growth of the embryo plant. Enough oxygen is present in the soil for the germination of seeds unless the soil is water-soaked.

64. Heat.—A certain amount of warmth is necessary before seeds will germinate. Each kind of seed has an optimum temperature at which it germinates best. It has also a minimum and maximum temperature, the lowest and highest at which it will germinate. The optimum temperature for germination usually is a very few degrees (1 to 4 degrees) higher than the temperature at which the plant makes its best growth. From 60 to 80 degrees F. is satisfactory for the germination of most seeds, but there are exceptions. Seeds

of many tropical plants germinate at 100 degrees F., while those of some maples germinate just above the freezing point. Seeds with thick hard shells generally require higher temperatures than those with thin coats.

65. Media for germination.—Seeds will germinate in any material in which sufficient amounts of heat, moisture, and oxygen can be maintained, provided there are no injurious (toxic) substances present. In nature the soil is the medium for germination.

For study, seeds can be germinated in boxes of soil or sand in a room where the proper temperature is maintained, or outdoors if the time of year and climate permit. Sawdust (not oak or redwood sawdust) is a clean and convenient medium in which to grow seeds for study purposes. The sawdust can be placed in small boxes or flats and should be kept moderately moist (not wet) and at the correct temperature.

Seeds may be germinated by rolling them up in sheets of blotting paper, or newspaper. The roll can be tied with a string or rubber band and should then be dampened and stood on end in a jar containing a little water. The water rises in the roll and keeps the seed moist. By placing the seeds in rows across the roll, a large number of samples can be tested at the same time.

Another kind of germinator can be made by placing sheets of blotting paper in a platter, placing the seeds between the moist blotting papers, and covering with a similar dish to retain the moisture.

Small seeds may be germinated by placing them on moist blotters in a saucer, and covering them with an inverted tumbler. When thus placed, they may be examined at any time without being disturbed.

Germination tests are useful in determining the value of seeds for planting purposes. If they do not sprout within the proper time, they are without vitality and are quite worthless.

The fact that the seeds sprout, however, does not show that they are sufficiently viable to produce mature plants, but indicates merely that they have not lost all vitality.

66. Adulterated seed.—Sometimes inert material, old seeds, and other seeds resembling those desired are mixed with good seed. Inert material and seeds of different kinds can be detected by examining them with a microscope. Germination tests will reveal the presence of old seed. Sometimes they can be told by their color.

67. Special methods of causing seeds to germinate.—Certain seeds are benefited by special treatment. The value of stratification in softening and cracking hard shells has been mentioned.

Soaking for a few hours in water to hasten germination is practiced with pear and apple seeds, corn and many vegetable seeds. The soaking should be stopped as soon as the seeds have swollen, and the planting should take place immediately.

Seeds having hard thick coats may be treated by scalding. Boiling water should be poured over them and allowed to cool. The seeds should remain in the water until they show signs of swelling. Seeds of the canna, certain locusts, a few conifers, and the Kentucky coffee-tree are examples of seed treated in this manner.

Many seeds with hard coats are benefited by being soaked in acids. Clover and alfalfa seed are soaked in sulfuric acid for a few minutes, and then washed thoroughly in water. When it is necessary in plant-breeding to plant the seeds of the blackberry, raspberry, or dewberry, soaking them a short time in vinegar is advisable. Seeds of the sweet-flag, pond-lily, arrowhead, cat-tail, and many of the sedges are benefited by weak acid treatments.

Mechanical treatments, such as filing, grinding, or clipping, are practiced on some hard-coated seeds (among which are the wild cucumber, canna, and olive) as an aid to the entrance of water. A portion of the coat is removed down to the embryo.

68. Planting seeds.—While proper depth of planting depends on the soil and kind of seed, as a general rule it is safe to plant seeds at a depth four times as great as their diameter. They must be deep enough to escape drying out, but should not be so deep as to have difficulty in forcing their tops through the soil.

Seeds may be planted in the greenhouse, in boxes known as flats, in hotbeds, or in the field. If flats are used, they should not be too large. Flats 3 to 5 inches high, 12 inches wide, and 18 inches long are convenient to handle. Another satisfactory size is 3 x 18 x 18 inches. It is advisable to put some gravel in the bottom of the flats to provide drainage. The remainder of the box should be filled with garden loam. A good soil for this purpose is made by mixing leaf-mold or rich loam with clean sand in about equal proportions, to which is sometimes added 1 or 2 per cent of ground bone. Seeds are planted at the proper depths in the flats. Very small seeds, like those of the petunia, may be sown upon a thin layer of powdered sphagnum moss placed upon the surface of the soil in the flats.

Seeds are frequently planted in hotbeds (see Plate I). Here heat is furnished by fermenting material placed in the ground. Usually a hole is dug about two and one-half feet deep and of an area equal to the size of the desired hotbed. Into this is put horse-manure and grass, which are kept moist and allowed to ferment for a few days until the temperature goes down to a safe point. Then the hole is filled with soil and the seeds planted. Over the bed is placed a frame with a glass covering.

A good sandy soil thoroughly cultivated and leveled is best for seeds which are to be planted in the open. The seeds are planted at the proper depth in rows and covered with soil. After the seeds are planted, the soil, unless heavy, should be compacted with the foot, board, or roller in order to bring the seed in contact with the moisture.

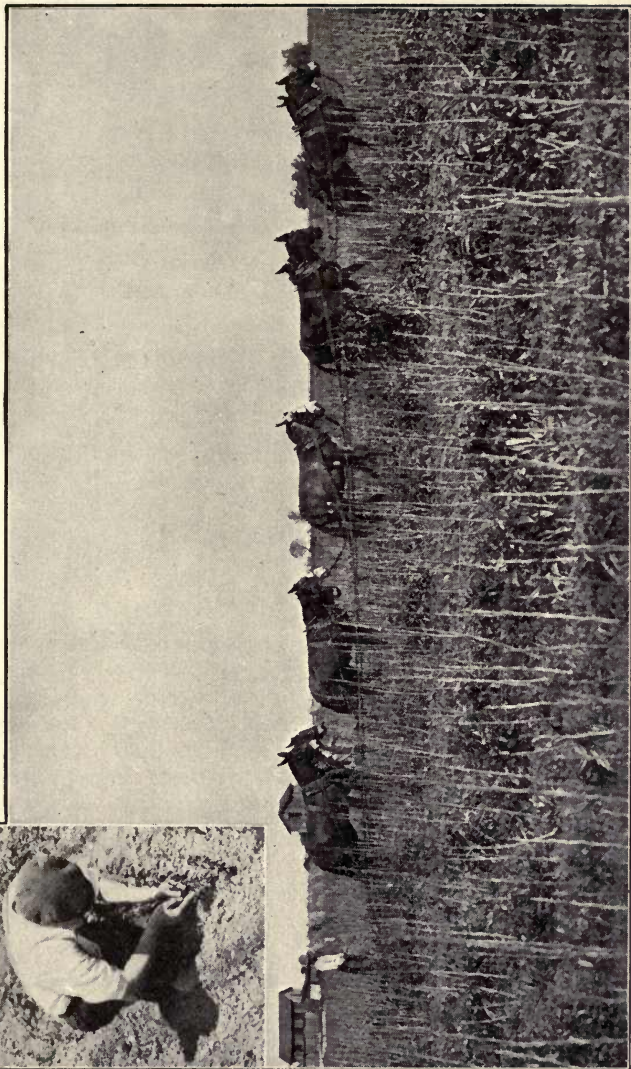


Plate II.—Digging nursery stock. Left-hand corner, a budder at work.

69. Time of germination.—The time required for germination varies with the kind of seed from a few days to a month or more, a fact which must be taken into account in the planting. Nursery catalogues and books on gardening frequently give the time required for germination of various seeds.

70. Transplanting.—Young plants are sometimes started in the greenhouse, and later planted out-of-doors. They may be transplanted from flats or hotbeds into coldframes before they are set out in the field. Coldframes are similar to hotbeds except that no heating material is used. The sun shines through the glass frame during the day, warming the bed, and at night the covering keeps the heat from radiating too rapidly and prevents frost from injuring the plants. Sometimes young plants are placed in pots and set out-of-doors before being planted in the open, or repotted into larger pots from small ones.

EXERCISES

EXERCISE I.—Structure of seeds.

Materials.—Seeds of corn, pumpkin, bean, pea, and other plants; knife; dissecting pin; magnifying glass.

Procedure.—Prepare seeds in the manner suggested in paragraph 49. Locate in each the hilum, micropyle, cotyledons, plumule, and caulicle. Classify the seeds examined into monocotyledonous and dicotyledonous seeds. Prepare a table showing wherein the seeds examined are alike in structure and wherein they differ. Make outline drawings of a few types of the seeds examined, labeling the parts.

EXERCISE II.—Growth of the plant parts.

Materials.—Seeds similar to those studied in the preceding exercise; small boxes; sawdust or clean sand.

Procedure.—Plant seeds in boxes filled with sand or sawdust kept moist, and dig up some every few days to determine the manner of growth of the parts. Observe what parts of the plant the plumule and caulicle become. What becomes of the cotyledons in each case? Write your observations as to how plants grow and illustrate with outline drawings.

EXERCISE III.—Effect of temperature on plant growth.

Materials.—Seeds; small boxes; sawdust, sand, or soil.

Procedure.—Plant the same kinds of seeds as were used in the preceding experiment in several boxes of sand or sawdust. Supply each box with the same amounts of moisture, but keep them at different temperatures. Note the difference in growth at the various temperatures. Write your conclusions as to the effect of these temperatures on growth.

EXERCISE IV.—Effect of moisture on the growth of young plants.

Materials.—Same as in preceding exercise.

Procedure.—Plant seeds in boxes in the same manner as in Exercise III. Keep the boxes supplied with different amounts of water. Note the effects of the different amounts of water on the germination of the seeds and the growth of the young plants.

EXERCISE V.—Effect of soaking seeds.

Materials.—Peas, corn, and other seeds.

Procedure.—Plant some seeds which have been soaked for a few hours, and some of the same kinds unsoaked. Which come up first?

EXERCISE VI.—Stratification.

Materials.—Hard-coated seeds similar to those mentioned in paragraph 58; boxes; soil.

Procedure.—Stratify some hard-coated seeds in the manner mentioned in paragraph 58. Note when they sprout.

EXERCISE VII.—Seed dissemination.

Materials.—As many kinds of seeds as possible.

Procedure.—Study as many seeds as possible to determine the mode of dissemination of each.

EXERCISE VIII.—Project exercise.

Materials.—Seeds used in project.

Procedure.—Students are requested to anticipate at this time the project which they will undertake if they have not already done so. They are requested to secure samples of seeds which will be utilized in this project and to examine them in the light of facts brought out in the chapter. Compare the seeds with those already examined, noting as closely as possible all similarities and differences. Note the length of time it takes for water to penetrate these seeds. If possible,

keep them in a moist warm place day and night (for example, between sheets of moist blotting paper) and note the length of time required for germination. Calculate the percentage of seeds which germinate. Divide the cost for a pound of seeds by this percentage and multiply by a hundred in order to ascertain the actual cost for a pound of germinating seeds.

CHAPTER IV

ASEXUAL PROPAGATION OF PLANTS ON THEIR OWN ROOTS

PLANTS are said to be propagated asexually when they are grown from buds or from tissues capable of developing buds. Some plants are propagated more easily asexually than by seeds. Moreover, many kinds when grown from seeds do not come true to type; that is, they do not resemble the parent plant in all respects. This is especially true of the fruit-trees; for example, if a seed from a Bellflower apple is planted, the resulting tree is prone to bear apples which do not resemble those borne on the parent tree. In asexual propagation, on the other hand, the resulting plants are true to variety.

71. Plants on their own roots, and on the roots of other plants.—Plants are propagated asexually on their own roots by such systems as layering, cuttings, division, and separation, and on the roots of other plants by budding and grafting.

72. Layering.—One of the easiest methods of propagating plants asexually is that of layering, in which the stems are rooted while still attached to the parent. The process is simple. A portion of a branch is covered with soil to a depth of three to six inches to keep the parts moist. With many hardwood plants it is helpful to injure the part from which the roots are to form by ringing, twisting, or cutting. The part is staked or weighted down to keep it in place. The following are some of the methods of layering.

73. Tip layering, in which the tips only of branches are placed in the soil, is illustrated in Fig. 27. The black raspberry and loganberry are propagated in this way.

74. Simple layering.—

In this form of layering, the branch is bent over and covered with soil so as to leave a portion of the top projecting, as shown in Fig. 28. Frequently the top is staked in order to keep it in an upright position. Usually the portion buried is encouraged to form roots

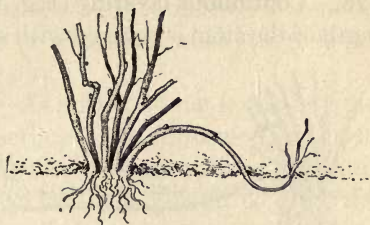


FIG. 27.—Tip layer, showing early growth of tip.

by wounding, which is done by scraping the bark, cutting a notch, or twisting. Many varieties of plants can be grown successfully by simple layering.

75. Serpentine or compound layering is used frequently when it is desired to produce several plants from a single

cane or vine. In this form of layering, the branch is covered with soil at various points where there are buds (Fig. 29);

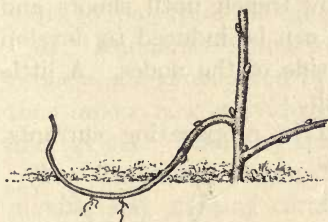


FIG. 28.—A simple layer.

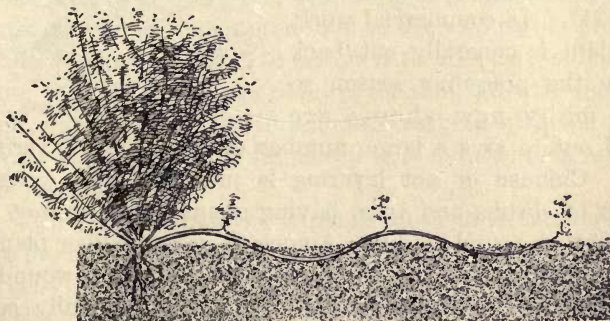


FIG. 29.—Serpentine layer.

otherwise it is treated the same as in simple layering. Compound layering is much used with vines.

76. Continuous layering (Fig. 30), in which a considerable length of the stem is covered with soil, leaving the tip exposed, is used only in cases of a few plants such as the osier and snowball, which produce roots readily from the buds.

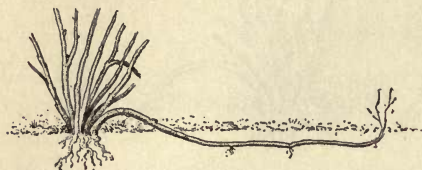


FIG. 30.—Continuous layer.

certain varieties of grapes and other vines which do not develop roots readily when layered in the ordinary way. The stem is pegged down in a shallow trench until shoots and roots start at the nodes. Roots can be induced to develop quickly by wounding the under side of the nodes. A little soil is finally placed in the trench.

78. Mound layering is used in propagating currants, gooseberries, and other plants having stiff stems which are difficult to bend over and layer by the usual methods. The stems are commonly wounded at the base and mounded up with soil (Fig. 31). In commercial work, the plant is generally cut back during the preceding season so that many new shoots are forced out to give a large number of shoots for layering.



FIG. 31.—Mound layer.

79. Chinese or pot layering is practiced with certain classes of shrubs and trees having stems which cannot be bent to the ground readily. Among these are rubber plants, crotons, and oleanders. Portions of the stems are wounded and bound in sphagnum moss. Sometimes specially constructed divided earthen pots are placed on the wounded

parts and filled with sand or other material. The moss or sand must be kept moist by frequent watering until the roots have developed. The use of this method is generally confined to the greenhouse or situations where there is little danger of the moss drying out.

80. Time for layering.—As a rule, spring is the best time for layering, although sometimes it is performed in the fall. Herbaceous plants of a succulent nature, such as geraniums, can be layered in summer, when it is difficult to grow them from cuttings. After layered plants have rooted, the new individuals are cut off from the parent and set out, in some instances in the fall, but in most cases in the following spring. Some plants, however, such as the spirea, take two years to root, from the time they are layered.

81. Runners.—Plants which, like the strawberry, produce runners, are propagated by a sort of modified layer. From the runners, new individuals are formed which may be cut off and set out. Plants of this type are easy to propagate.

82. Cuttings.—Propagation by cuttings consists in removing and planting certain portions of plants. Cuttings may be made from leaf, stem, tuber, root, or bulb, the parts most suitable differing with the species. A cutting must contain living tissue and be able to multiply its cells; it must have a growing bud or be able to produce one; and it must contain enough stored food to keep up its life processes while it is forming roots to enable it to take up food material from the soil. Cuttings require, for their growth, moisture, heat, oxygen, and light in amounts varying with the nature of the plant, and must be placed in a suitable medium until the roots develop.

With most plants, the cuttings must go through a callus-forming process before roots form. The callus is simply a growth of cells formed from the normal growing tissue of the cutting. In the hardwood cutting in Fig. 32, the callus will be seen as a rim proceeding from the cambium layer at the cut surface.

Roots do not usually develop from the callus, but callus formation generally must precede root formation.

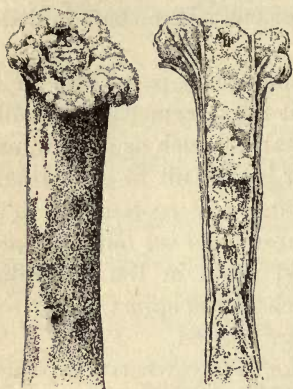


FIG. 32.—Callusing of cuttings. In the longitudinal section the callus originating at the cambium has forced out the several layers of bark.

83. Leaf-cuttings.—Some plants possessing thick fleshy leaves with an abundance of stored food can be propagated by leaf-cuttings. Leaves of *Bryophyllum* placed on moist sand in the cutting-bed will produce plants from the notches in the leaves (Fig. 33). Most leaves have to be wounded in order to be able to send out shoots in this manner. The *Rex begonia* leaf will produce plants if its ribs are wounded and it is pegged down in sand. It is not necessary to use the whole

leaf, a piece planted edgewise being sufficient. In the same way, tomato leaves, if the bud at the base is included, will produce plants. Other kinds which may be propagated in this manner are the cabbage, rose, lemon, and lilac, but few are so reproduced commercially. Leaf-cuttings produce plants true to variety except that they do not transmit the irregular white or yellow spots or blotches on leaves known botanically as variegations.

84. Tuber-cuttings.—Tubers are thickened underground stems having an abundance of stored food, and possessing buds capable of producing plants. The stems grow from the buds or eyes, and from the stems roots develop. When a portion of the



FIG. 33.—A leaf-cutting.

tuber is cut off so as to contain one or more eyes, and is planted, new individuals result. The Irish potato may be propagated in this way.

85. Root-cuttings.—Plants which naturally produce suckers¹ from the roots or which have the power of producing adventitious² buds from the roots can be propagated successfully by root-cuttings. The blackberry (Fig. 34), red raspberry, horse-radish, and *Rosa rugosa* are propagated commercially in this way. Many other plants, among them willows, poplars, osage orange, juneberry, plums, and cherries, can be propagated by root-cuttings, although most of these are reproduced more easily by other methods.

Roots for cuttings should be neither too large nor too small. As a rule, they should be at least as large as a lead pencil, but not over three-fourths of an inch in diameter. They are cut into lengths varying from one to four inches.

Root-cuttings may be stored in sand, and kept moist in a cool place until they form a callus. In the spring they may be removed and planted out-of-doors. Root-cuttings of plants which thrive in cool climates, such as blackberries, roses, and lilacs, can usually be grown out-of-doors. The more tender plants require bottom heat. In any case bottom heat hastens callusing. When root-cuttings are planted out-of-doors, the soil should be pressed down over them firmly but they should not be covered too deeply, seldom over an inch. The cuttings must have moisture and in many cases must be shaded. Root-cuttings produce plants true to variety with the exception that they, like leaf-cuttings, frequently do not transmit variegations.



FIG. 34.—Root-cutting of the blackberry.

¹ Sucker is the shoot of a plant from the roots or lower part of the stem; usually very rapid in growth and unfruitful.

² Adventitious (as a botanical term) means out of the proper or usual place.

86. Stem-cuttings.—Cuttings made from stems or branches must be planted right side up, that is, with the end which grew nearest to the root downward in the soil. For convenience, stem-cuttings can be divided according to the hardness and maturity of their tissue into three classes: (1) hardwood, mature or dormant cuttings; (2) herbaceous, soft-wood or active cuttings; and (3) semi-hardwood cuttings.

87. Hardwood cuttings (Fig. 35) are made from wood which has completed its growth and has matured. In moist



FIG. 35.—Hard-wood cutting of the currant.

tropical countries certain trees may be propagated by breaking off branches and planting them in the ground. In climates like those of the United States and Canada, propagation by hardwood cuttings requires more care. There is a great difference in plants in this regard; for example, pieces of the olive tree split into cordwood will produce roots and foliage if one end is placed in moist soil while it is still green, provided that a strip of living bark is present. Cottonwood fence posts set in moist soil have been known to develop into thriving trees. On the other hand, cuttings of evergreen trees root with difficulty.

88. Best time for making cuttings.—Hard-wood cuttings are taken either in the autumn or in spring. Cuttings made in the spring are usually planted in the field immediately.

Fall cuttings may be stored over winter for spring planting or in mild climates may be planted at once in the field. Fall planting, however, even in mild climates, involves risks. Cuttings of grapes, for example, are likely to rot in the winter because of the moisture in the soil. In cold climates, injury to the wood of the cutting from freezing is common. Hence, in general, it is best to store fall cuttings over winter for spring planting. They may be stored in sand or sawdust

just moist enough to prevent their drying out and, as a rule, should be kept at a low temperature (just a little above the freezing point) in order to keep the buds from starting. Storing over winter gives opportunity for the callus to form and sometimes for the roots to start by planting time in the spring so that the stored cutting is ahead of the spring cutting.

Sometimes, especially with hardwood cuttings difficult to root, bundles of them are buried with their base ends upward just beneath the ground on a well-drained knoll. This is usually done a few weeks before they are to be set out in the spring. The sunshine warms the upper surface of the soil, and callusing is greatly aided, while the tops of the cuttings are down in the cooler portions of the soil and the buds are kept from starting. It will be seen that this method is simply a means of securing bottom heat.

89. How to make hardwood cuttings.—Wood of the previous season's growth is used in making hardwood cuttings. The usual and convenient length for these cuttings is from six to ten inches. The cut at the base end is usually made just below or through a bud because a maximum supply of food is stored at that point, and, therefore, callusing takes place readily. The upper end is cut about half an inch above a bud. It is customary to include two nodes in each cutting, but with some plants, such as many varieties of grapes, a three-node cutting gives best results. When cutting wood is scarce or the nodes are so far apart that it is inconvenient to have two nodes, it is possible to make single-eye cuttings, as illustrated in Fig. 36. Single-eye cuttings are usually placed horizontally in sand with the bud uppermost, and are covered to a depth of a little less than an inch.



FIG. 36.—Single-eye cutting of the grape.

In planting hardwood cuttings in the spring, it is convenient to dig a trench and set up the cuttings in it from four to six

inches apart. The trench should then be filled with soil and the soil packed down firmly around the cuttings. When the earth is packed tightly, it prevents the buds below the surface from producing shoots. Sometimes all the buds except those which are to be left above ground are removed. Only one or two buds should project out of the soil.

90. Cuttings of coniferous plants.—Many conifers are propagated by hardwood cuttings. Small cuttings are made of the mature wood. The leaves, except those at the lower end, are left on. The cuttings are made and planted in the autumn in sand in a cool greenhouse. They are slow to root. Spruce, for example, generally requires over a year, and many other evergreen plants need one or two years.



FIG. 37.—Softwood cutting of the carnation.

91. Softwood cuttings (Fig. 37).—Nearly all plants can be propagated by softwood cuttings. Many herbaceous¹ plants are propagated in this manner altogether. As a rule, the part near the tip of the branch or stalk makes the best softwood cutting. Material for softwood cuttings should not be taken from stems that have already formed wood-fibers, as such cuttings do not root readily. If the stem from which the cutting is to be made breaks when bent sharply, it is suitable, but if it bends without breaking it should not be used.

92. How to make softwood cuttings.—The base end of the cutting is usually cut at a node, although in some instances better results are obtained by cutting between the nodes, owing to the fact that the tissues at the nodes have hardened.

¹ An herbaceous plant is one having a soft or succulent stalk or stem, that dies to the root every year, and is thus distinguished from trees and shrubs, which have ligneous, or hard woody stems.

A few leaves are left, but most of them should be removed to lessen transpiration. Softwood cuttings should usually be quite short.

Softwood cuttings, as a rule, should be kept moist from the time they are made until they are rooted. It is true, however, that with some succulent plants, such as the cactus and geranium, better results are secured by allowing the cuttings to wilt before they are planted.

93. Planting softwood cuttings.—The greenhouse is the best place in which to plant cuttings of this nature. They should be placed in sand which should be packed closely about them. Bottom heat is desirable. After callus formations and roots begin to appear, the cuttings may be transplanted into pots or into flats of soil. The cuttings should be protected from bright sunlight during the hot parts of the day.

94. Semi-hardwood cuttings are made from those parts in which wood fibers have started to form. They are used for propagating hardwood plants. Many roses, oleanders, hydrangeas, and the like can be propagated successfully by semi-hardwood cuttings. In many of the hardwood plants, it is advisable to secure at the base of the cutting a heel of the older and harder wood. Sometimes a mallet-cutting is made for the same reason. These cuttings are somewhat similar to a mallet in shape, the short cross-piece being of the older wood. The grape is often propagated by mallet-cuttings.

95. Offsets.—Some plants produce rosettes of leaves known as offsets, which are in fact a kind of bud. These can be removed and set in soil, where they root readily. The *Cotyledon* (*Echeveria*) is an example of a plant readily propagated in this way. Many palms are propagated by offsets.

96. Tuberous roots.—Many plants, such as the dahlia, which produce thickened roots, may be propagated by the

planting of portions of the roots with a part of the top attached.

97. Tuber.—The distinction between a tuber and tuberous roots should be borne in mind. The latter is a root proper, but a tuber is a thickened underground stem, such as in the potato and Jerusalem artichoke. The so-called eyes of the tuber are really buds, which, when removed with a portion of the tuber and planted, are capable of producing new plants as described under cuttings.

98. Bulbs and corms.—Bulbs are modified buds. Plants which produce bulbs generally have a short growing season and a long dormant season. Bulbs are divided into two classes: scaly bulbs, which have narrow and usually fleshy scales, loosely arranged, as in lilies; and tunicate or laminate bulbs having broad scales closely fitting, as in the onion.

Bulbous plants produce small bulbs at the bases or tops of the parent bulbs, or among the bulb scales. They are propagated artificially by removing the small bulbs (bulbels) and planting them at the proper time. Even the thick fleshy scales of some bulbs may be made to grow by being removed and treated like single-eye cuttings.



FIG. 38.—Corm of gladiolus growing about old corm. Notice the cormels at the base of the corm.

Small bulbs, usually called bulblets, are sometimes formed on the stems of plants in the axils of the leaves, as in the tiger lily, or in the flower-clusters, as in the onion. Bulblets may be planted in the same manner as the ordinary bulbs. The bulb of the hyacinth and some other plants may be made to produce, by wounding, more small bulbs than would

otherwise be the case.

Corms (Fig. 38) are solid bulbs having rings of compact tissue instead of scales. The Indian turnip, gladiolus, and

crocus are examples of plants producing corms. Usually they propagate themselves by forming a new corm above the old. They are propagated in the same manner as bulbs.

99. Media for growth.—Sand and sawdust have been mentioned as suitable media for starting cuttings. On account of its ability to hold the proper amount of moisture, fairly coarse sharp sand is most generally useful. Very coarse sand does not hold sufficient moisture, while very fine sand contains too much moisture and packs so closely as to interfere with the supply of oxygen. Therefore, sand of medium texture is best. In order to lessen the liability of disease, there should be no organic matter present in the cutting-bed. Sand from fresh water streams is good. Sand from any sand-pit may be used with safety after it has been exposed to the action of weather for a month or two. A convenient way to cleanse sand for the cutting-bed is to place it in a water-tight container and wash it with a stream of water from a hose until the run-off is clear.

100. Temperature.—The air above the cutting-bed should be cool enough to discourage the growth of the tops of the plants until roots form. Sufficient bottom heat should be given to stimulate the growth of tissues. The bottom of the cuttings should be kept from 5 to 15 degrees warmer than the air above ground, especially in the propagating of plants with soft tissue.

101. Apparatus for growing cuttings.—Various ways of regulating temperature and moisture conditions have been devised. A few kinds of cuttings, such as those from oleanders, will produce roots if the cutting is kept in a moderately warm room and the base end is placed in a bottle of water. Sometimes a small unglazed flower-pot is placed inside of a large one and the spaces between are filled with moist sand in which the cuttings are planted. The hole in the bottom of the inner unglazed pot is plugged and the inner pot is filled with water which seeps through gradually, thus keeping the

sand moist at all times. Propagating ovens (Fig. 39) are small cabinets in which bottom heat is provided by means of a lantern or other heating device placed under a pan of water above which is the sand containing the cuttings. Over the top of the cabinet is a glass sash which can be raised

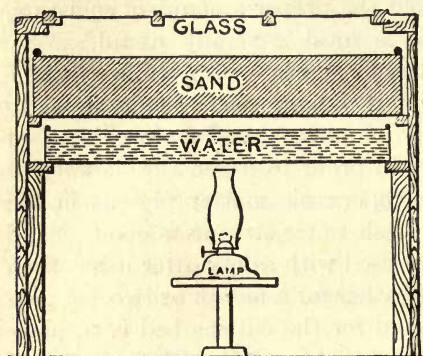


FIG. 39.—A simple propagating oven.

or lowered to regulate the temperature. In hotbeds, bottom heat is provided by fermenting manure and organic matter. By far the most satisfactory arrangement for rooting most cuttings is the cutting-bed in a greenhouse. Sand is placed in the cutting-bed and bottom heat is

furnished by steam or hot-water pipes running under the bed. Ventilation is provided so that the proper air temperature above the plants may be maintained. Coldframes are sometimes used for setting out cuttings previously rooted in cutting-beds provided with bottom heat. This hardens the plants and prevents them from becoming too tall and spindling. Many hardwood cuttings, such as those of the currant and grape, can be grown by planting them out-of-doors in well-drained sandy soil (Fig. 40). In such cases the heat of the sun warms the soil but, of course, the heat at the bottom of the plant is not so even as that in cutting-beds in the greenhouse. Many bulbs, tubers,

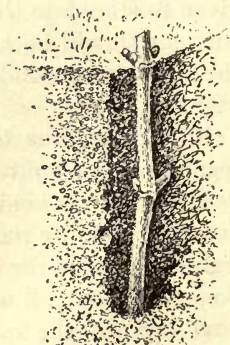


FIG. 40.—Method of planting cuttings in a trench.

and tuberous roots will start to grow very readily out-of-doors.

EXERCISES

EXERCISE I.—Propagation by cuttings.

1. Root-cuttings.

Materials.—Knife; roots of blackberry or similar plants.

Procedure.—Make cuttings from two to six inches long. The shorter length is suitable if the school possesses greenhouse or hotbed facilities. The longer cuttings should be made if they are to be grown out-of-doors. The cuttings should be kept during the dormant season under cool and moist conditions and should be supplied with heat as the growing season approaches. As spring approaches, place the cuttings in the ground about three inches deep and keep watered, and cultivated.

2. Herbaceous cuttings.

Materials.—Herbaceous plants; cutting-bed; or place out-of-doors.

Procedure.—Make some leaf- and stem-cuttings of herbaceous plants according to methods described in the text. Plant the cuttings in sand in flats or in the greenhouse, or, if the time of year is suitable, out-of-doors.

3. Hardwood and semi-hardwood cuttings.

Materials.—Canes of currant bushes, or grape vines.

Procedure.—If the cuttings are to be made from currant bushes, wood of the current season's growth must be used. Make cuttings from six to eight inches long, following the suggestions in the text on hardwood cuttings. Store the cuttings during the winter in the manner mentioned in the text. They must be kept very slightly moist and be protected from heavy frosts. As soon as the weather moderates in the spring, place the cuttings in the open ground with the upper bud just protruding above the surface. Pack the ground tightly around the cuttings. The cuttings will root readily if kept cultivated and supplied with moisture.

EXERCISE II.—Propagation by layering.

Materials.—Black raspberry bushes; grape vines; osier; snowball; currants; gooseberries.

Procedure.—Layer plants according to methods described in the text. Keep a record of the different plants, method of layering, date of layering, and conditions under which they are layered. Examine them from time to time and report on their condition.

EXERCISE III.—Callus formation.

Materials.—Stored or planted cuttings.

Procedure.—Examine cuttings from time to time. Draw a callus. What factors are necessary for callus formation? Which of the cuttings examined callus most readily?

EXERCISE IV.—Project: If the student is contemplating a project involving propagation by cuttings, he should begin a systematic study of the plants he intends to use so as to be ready with cuttings at the opportune time. The following projects are suggested: Propagating and growing blackberries, raspberries, currants, loganberries, gooseberries, strawberries, or ornamental plants.

CHAPTER V

ASEXUAL PROPAGATION ON THE ROOTS OF OTHER PLANTS

PLANTS are propagated on roots other than their own by means of budding and grafting, which consist in inserting a part of one plant in the stem or root of another with the object of causing the two to grow together. The portion of a plant inserted in another is called a cion (or scion). The plant on which the cion is placed is known as the stock. Grafting can be done best in late winter or early spring when the tissues are in a resting stage, while budding is performed in late spring, summer, or early autumn when the tissues are active.

102. Uses of budding and grafting.—By means of budding and grafting it is possible to perpetuate varieties which do not come true to seed, to propagate plants which do not produce sufficient seed or which do not grow readily either from seed or by asexual methods other than budding or grafting, and to adapt plants to unfavorable conditions by the use of suitable stocks.

103. Limits of grafting and budding.—Commercially, grafting and budding are limited to exogenous plants of types which unite readily. Although there is no absolute rule to follow, in general it is safe to say that the closer the botanical relationship the more certain is the union. It is only in a few instances that it is possible to graft members of one family of plants upon those of another. One would not expect, for example, that the peach, a member of the Rose family, could be grafted upon the oak, a member

of the Beech family. Members of different genera of the same family may or may not unite. For example, in the Rose family it is possible to graft some kinds of pears (genus *Pyrus*) upon the quince (genus *Cydonia*), but it is not possible to grow the apple (genus *Pyrus*) upon the peach (genus *Prunus*). It may be said at this point that stone-fruits will not grow on pome-fruits and *vice versa*. Different species of the same genus commonly, though not always, unite successfully; for example, in the genus *Prunus*, the peach (species name *Persica*) can be united with the common plum (species name *domestica*). Varieties within a species commonly unite when budded or grafted; thus, any two varieties of peaches will unite, or any two varieties of apples. While botanical relationship may indicate the probabilities as to the ability of any two plants of different kinds to unite, experimentation is the only means of ascertaining the facts with finality.

104. Essential points in grafting or budding.—Success in grafting or budding depends on the observance of the following rules:

1. The stock must be suitable to the cion.
2. The operation must be done at the right time of year and under proper conditions.
3. The cambium tissue of the cion must be in contact with the cambium of the stock.
4. The wounds must be prevented from drying out.
5. Proper attention must be given the tree after grafting or budding.

105. Budding.—Though a few kinds of trees are better adapted to one process than to the other, in general, as far as propagation itself is concerned, it makes very little difference whether budding or grafting is employed. The choice of method will depend on considerations of convenience. Budding is performed during the growing season. Budding can be done faster than grafting, and more trees can be

budded with a given amount of cion wood than can be grafted. These are important considerations when many trees are propagated.

106. Types of budding.—Named according to the manner in which the budding is performed, the kinds are: shield-budding; twig- or spur-budding; flute-, patch-, or veneer-budding; plate-budding; and ring- or annular-budding. Shield-budding is by far the most common, the other methods being used only in cases where shield-budding does not give satisfaction.

107. Shield-budding.—The main steps in shield-budding, as in other methods, are:

1. Preparing the stock.
2. Selecting, preparing, and keeping the bud-stick.
3. Cutting the stock for the bud.
4. Removing the bud from the bud-stick and inserting it in the proper place in the stock.
5. Tying the bud.

After-treatment necessary to the production of a tree includes the following:

- a. Cutting the ligatures to prevent girdling.
- b. Cutting back the top of the budded tree at the proper time to force the bud into growth.

108. Preparing the stock previous to budding.—The bark of the stock should peel readily. If the bark is tight and does not peel, it is advisable, if possible, to irrigate the rows a few days previous to budding. All leaf growth and suckers below the point where the bud is to be placed upon the stock should be rubbed off, but this should be done not longer than three days before budding the trees; otherwise the bark is likely to tighten.

109. Selecting bud-wood.—Except in dormant budding to be explained later, bud-wood should be well-hardened wood of the current season's growth. It should be taken from bearing trees in order that there may be no mistake as

to the variety propagated. Healthy twigs about the size of a lead-pencil or smaller are cut from the tree, wrapped in moist cloth to prevent drying, and taken to a shady place for the preparation of the bud-sticks. In the preparation of the bud-stick, the leaves are cut off in such a manner as to leave a small portion of the petiole with each bud as is shown in the illustration (Fig. 44). This protects the bud as it is pushed down in the bark of the stock. The prepared bud-sticks are cut into convenient lengths and placed in bundles with the large ends together. The bud-wood should be used as soon as possible, but may be kept for several days if stored in a cool place, and covered with moist wrappings. In some instances bud-wood is kept for several weeks. Orange bud-wood is frequently stored in this way in moist sphagnum moss wrapped in burlap. The bud-sticks may be prevented from drying out in the field by wrapping them in moist burlap or heavy bags. If the large ends of the bud-sticks are near the open end of the wrapping, the sticks can be pulled out as needed without disturbing the remainder of the bundle.

The part of the twig usually possessing the best buds is shown in Fig. 44. The buds near the tip are usually spongy and are not so good as those further back. The buds near the base of the twig are usually not well developed and hence are not suitable.

110. The operation of budding.—Individual budders differ in many minor points which are matters of personal preference, but the main parts of the methods are the same. The following is a description of one of the methods of shield-budding.

111. Position.—Plate II shows the proper position for the budder. When many trees are to be budded, the budder usually works with one knee on the ground and rests his shoulder over the other knee to relieve the strain on his back.

112. Budding-knife.—The budding-knife should be very thin, round near the point, and of the best steel (Fig. 41). It should be sharpened on a fine whetstone and stropped to a razor edge from time to time in the field. A sharp knife is one of the essentials for success in budding.

113. Cutting the stock.—The size of stock most convenient is about that of a lead-pencil, but stocks larger or smaller can be budded. More skill is required to bud small stocks than large. A cut from one to one and one-half inches long is made parallel with the sides of the tree by holding the knife and guiding it with the finger as shown in Fig. 42. A cross-cut is then made (Fig. 43) with a slightly rolling motion of the knife to open the bark for the insertion of the bud. The cuts are just deep enough to go through the bark. Usually the cut should be on the side of the tree away from the sun and as low on the stock as possible.

114. Inserting the bud.—The bud to be inserted in the stock is cut from the bud-stick, as shown in Fig. 44. The knife is steadied by holding the thumb in the

position indicated, the blade entering below the bud and coming out above. The part of the bud-stick cut out with the bud is known as the shield. Care should be taken to have both ends of the shield long enough to keep the bud from drying out after it is tied. Usually a little of



FIG. 41.—A budding-knife.



FIG. 42.—Making the longitudinal incision preparatory to budding. Note the position of the knife and forefinger.

the wood is removed with the bark. Since the cambium of the bud should have plenty of surface in contact with the cambium

of the stock, some budders prefer to take out the wood, leaving only the bark, but this is unnecessary except in a few special cases.

As the knife comes up through the bark, the top portion of the bud is grasped between the thumb and the knife-blade so as to be in position (Fig. 44) to be placed immediately in the "T" cut in the stock. The bud is inserted and pushed down with the thumb (Fig. 45) or with the point of the knife-blade. The tip or lower end of the shield should be pushed a little way below the vertical cut. The top should not come above the cross-cut (Fig. 46) because any portion

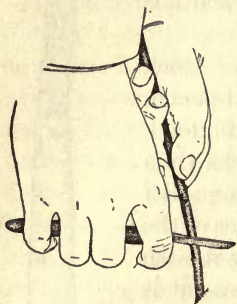


FIG. 43.—Making the cross-cut of the "T" with a rolling motion of the knife.

projecting could not unite with the stock and would probably cause all of the bud to dry out and die. With a little practice, the shield can be cut just the correct length, but if it should be too long the top can be cut off with the knife after the bud is in place.

115. Tying.—The bud must be tied firmly in order that the two cambium layers may be held closely together and the bud prevented from drying out. Various materials have been utilized for tying, but string is to be preferred, especially in arid climates. Raffia (consisting of fibers of a large palm) is also used. When raffia is employed, it should be soaked for a number of hours and tied while wet. Fig. 47 will make clear the manner of tying. With string three wraps are usually made below the bud and four above it. The

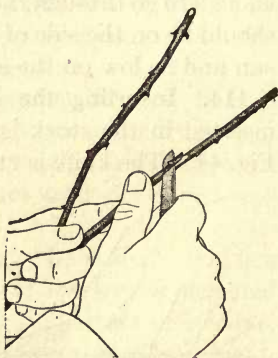


FIG. 44.—Cutting the bud.

important point in wrapping is to keep the string tight, and to wrap so that all portions of the bark are held down firmly.

116. Removing the ligatures.—In order to prevent girdling, in about ten days after budding the strings are cut on the side of the tree opposite the bud.

117. Topping the budded trees.—When it is desired to force out the bud, the top of the tree is cut off to cause the sap and food material to go to the bud. Sometimes the top is cut off at one operation to within a half inch of the bud. Many prefer to cut off a part of the top first, so as to avoid shocking the



FIG. 45.—Inserting the bud.



FIG. 46.—The bud inserted. Notice that the point of the bud-shield is down under the bark and that the flaps of the bark overlap the edge of the shield.

tree, and later to cut back to the proper distance. When it is desired to produce a tree the same season as it is budded, as in June-budding, topping must be performed in that season, but in fall-budding, since it is undesirable to have the buds forced out the same season, topping is not done until the following spring.

118. Other forms of budding.—While shield-budding is the common form, other methods are used in special cases. Spur-budding, patch-, and ring-budding are employed on thick-



FIG. 47.—The bud tied with string. The string is tied tightly and is held by the end being pulled under the last wind. Although a portion of the edges of the bark shows between the winds of the string, the flaps are held down securely at all parts.

barked trees where shield-budding does not give good results. Twig- or spur-budding differ from shield-budding only in that a spur or short twig on which there is a bud or buds

is left on the shield instead of the single bud. (See Fig. 48.)

119. In flute-, patch-, or veneer-budding a rectangular piece of bark is removed from the stock and replaced immediately with a piece of bark of similar size and shape bearing a bud of the variety to be propagated (Fig. 49).

There are special devices to facilitate the cutting of the bark to uniform size, but an ordinary knife can be used.



FIG. 48.—Twig-bud cut ready for insertion.

120. Ring- or annular-budding is similar to flute-budding, except that a ring of bark is removed all the way around the tree and is replaced with a similar ring cut from the cion.

121. In H-budding the bark of the stock is cut as shown in Fig. 50. The flaps of the bark are raised, and a piece of bark from the cion

of proper size, and bearing a bud, is placed so that its cambium comes in contact with the cambium of the stock, and the flaps are bound over it. In H-budding and in other special methods, in addition to tying the bark in place, it is frequently of advantage to wax over the cut surfaces.



FIG. 50.—H-budding.

122. Chip-budding is much used on dormant stocks when the bark will not slip. In this form, a mortise

is made in the stock and a chip containing a bud cut from the cion wood is forced into it. (See Fig. 51.) The chip is tied in, and when above ground is usually waxed. In chip-budding on grape roots, where this method is much used, the chip need not be tied or waxed as the part is covered with soil.



FIG. 49.—Patch-budding. A, stock prepared for patch by removal of piece of bark of same size as patch. B, the patch-bud.



FIG. 51.—Chip-budding.

123. Fall- and June-budding.—In fall-budding, the buds are inserted late enough so that they do not produce shoots the same season, but unite and remain through the winter as dormant buds. In the following spring, the shoots are forced out. It takes two seasons in the nursery to produce a tree by this method, which is the one most practiced.

June-budding must be performed early enough to give the bud time to produce a shoot the same season. It is possible to obtain a salable nursery tree in one season by this method.

124. Dormant-budding is practiced when it is desired to bud trees just as soon as the bark slips easily in the spring. At this time of year it is impossible to obtain buds from the current season's growth. Hence, buds must be obtained from the last year's wood. Such wood, however, is subject to winter-kill and the buds may be injured without showing it clearly. On this account the bud-wood is taken from the tree and stored over winter in sawdust or sand kept very slightly damp. In the spring just as soon as the bark slips, the dormant buds are cut and inserted from the stored cions exactly as in the case of June-budding.

125. Top-budding.—The foregoing methods apply especially to nursery stock. Sometimes it is desired to bud the tops of trees to certain varieties. In that case, the branches are cut back to force out the young shoots and the budding is done on these shoots. Usually, however, grafting is used in top-working trees.

GRAFTING

Grafting, like budding, consists in inserting the cion in the stock so that the cambium layers come in contact. In grafting, however, the cion usually contains more than one bud. Grafting may be done while the trees are dormant, in late winter or early spring before the sap starts to circulate.

126. Parts of the tree which are grafted.—Grafts may be placed on the roots, crown, stem, branches, or tips of the branches.

Root-grafting is much used in propagating nursery stock. The grafts are usually made by the whip method¹ on roots previously dug and stored for the purpose.

Crown-grafting is made on the crown of the tree near the ground, usually by the bark or the modified cleft method. Large crowns can be grafted in this manner and trees with damaged tops can be saved. This form of graft has been employed much in Europe to save the trees damaged during the war. Crown-grafting by the cleft method is used on nursery stock also. The small trees are cut off near the ground and grafted.

In trunk- or stem-grafting, the whole top of the tree is cut off and the cions are inserted into the trunk.

Branch-grafting is a common method on old trees. The branches are cut off where they are of convenient size (from 1 inch to 2 inches preferred) and are usually grafted by the cleft method.

In tip-grafting, small cions are grafted on the twigs near the ends. While this sort of grafting is difficult to perform satisfactorily, it is coming into use with plant-breeders who desire to test out new varieties. By tip-grafting, the cion can be made to produce fruit more quickly than in any other way.

127. Grafts classified according to manner of their making.—Many methods of grafting have been devised. Whip or tongue, cleft, bark, kerf, veneer, saddle, bridge, and inarching or approach-grafting are some of the most common forms.

128. Whip- or tongue-grafting is used on small stocks. It is common in root- or bench-grafting. The stock and cion are both cut obliquely with one stroke of a sharp knife. A

¹See paragraphs 127 to 137 for a discussion of the various methods.

slanting cut is then made in the stock and cion, as shown in Fig. 52, and the two parts are forced together as illustrated. If the graft is made properly, no light should show through. The tongues should not project but should come to the position shown in the illustration. If they project, they may be cut off to the proper length. The grafts are wound with a few turns of waxed knitting cotton which breaks easily, so as not to cause girdling when growth takes place. In commercial establishments, the grafts are wound by a machine. Many propagators do not wind the grafts at all, but fit them firmly together. If whip-grafts are made on parts above ground, the grafts must be waxed at all cut surfaces.

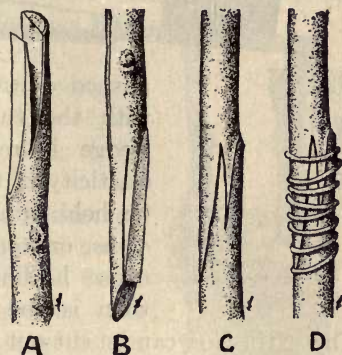


FIG. 52.—Whip-grafting. A, stock cut ready for cion; B, cion cut; C, graft completed; D, graft tied with waxed yarn.

129. **Cleft-graft** (Figs. 53-57).—This is one of the oldest grafts. It is used for the most part on branches three-fourths of an inch in diameter or larger. The branch to be grafted is first sawed off. The stub is then split with a grafting tool and a wedge put in to keep the cleft open. The cion is



FIG. 53.—Splitting the stock with the grafting tool which is driven in with a wooden mallet.

cut obliquely on both sides as shown in Fig. 55, a bud being left low down on the cion just above the place where the cut surfaces begin. The wedge of the cion is left a little

wider at the outside part than it is on the inside portion. The cion is inserted as shown in the figure in such a manner

that its cambium and that of the stock come together at some point.

The cion should be

pushed down until the lowest bud is even with the top of the stock. When the wedge is removed from the cleft, the elasticity of the stock causes the cion to be held firmly. It is well to insert two cions, one on either side of the stub, because healing takes place more rapidly than is the case if only one is inserted.

The extra cion can be cut out later. On large stubs a number of cions are often used to facilitate healing. All cut surfaces should be covered with grafting-wax, including the top cut surfaces of the cions.

Frequently in cleft-grafting, which is much used in the top-grafting of old trees,

the stub is split at one side of the center, or in several places, so that the cleft does not run through the central portion of the tree. As the clefts can thus be made smaller than if they go through the center, they heal faster.

130. Kerf-graft or inlaying.—In this graft a triangular piece is cut out of the stock, usually by means of a special



FIG. 55.—Cions cut for insertion in the cleft.

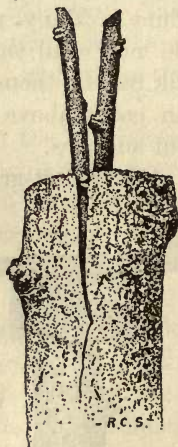


FIG. 56.—Cions inserted in cleft ready for waxing.

tool, the base of the cion is cut to fit, and is inserted in the space in the stock. The cion must be tied firmly in place and waxed. The kerf-graft is preferred

by many to the cleft for stocks having a pith in the center.

131. Bark-graft.—When the bark will peel, large stocks are frequently grafted by this method. The stock is cut off and vertical slits are made in the bark where the cions are to be inserted. The cions are cut as in Fig. 58 and the tongues inserted under the bark. The top of the stock is then wrapped tightly with string and waxed over.

132. Veneer-grafting is used almost entirely in the greenhouse. A shallow notch is cut in the stock, and the cion is fitted in the notch. The cion is tied in with raffia and the grafted plant is kept in the greenhouse where there is plenty of moisture in the atmosphere.

133. Side-grafting.—In this graft a cut is made in the side of the stock,

and the cion, trimmed so that its base is wedge-shaped, is inserted in the cut. Out-of-doors the wounds must be waxed. Side-grafting is much used with stone-fruits like the peach (Fig. 59).

134. Saddle-grafting.—In grafting many greenhouse plants, the stock is cut in the shape of a wedge, and the cion is split or notched, and placed over the wedge.

135. Inarching or approach-grafting.—In a few special cases, inarching is useful.



FIG. 57.—The graft after being waxed.



FIG. 58.—Bark-graft, showing method of cutting cions and inserting in stock.

The method consists in uniting two plants while they are on their own roots. A piece of the bark is cut from the stems of the stock and cion and the two wounded portions are tied tightly together. Waxing is necessary. After the union has taken place, the top of the stock is cut off just above the graft, and the stem of the cion just below the graft, leaving the top of the cion on the stock.



FIG. 59.—Side-graft.

136. Bridge-grafting.—Trees which have been injured by being girdled by rabbits or rodents can frequently be saved by bridge-grafting. This form is also useful in cases in which pear-blight has made it necessary to remove portions of the tree trunk. In bridge-grafting the bark around the edge of the wound is first trimmed to a smooth edge, and the ends of a small branch of the proper length are cut obliquely and inserted under the edges of the bark. Such cions are placed at intervals of every two or three inches (Fig. 60). Sometimes the ends of the inserted cions are nailed down. The ends of the cion and edge of the bark must be waxed, and all the injured surfaces should be painted. As the sap circulates through the inserted cions, which get larger from year to year, the effect of the loss of bark by girdling is at least partially remedied.



FIG. 60.—Bridge-graft showing cions inserted.

137. Grafting materials.—In grafting it is necessary to protect the injured tissues by some coating or wrapping which will prevent drying out and keep out organisms which cause decay. In early days (and to some extent at the present time in Europe) mixtures of clay and cow manure were applied to grafts. Grafting-wax, however, has for a

long period been the standard material for this purpose. Most grafting-waxes consist of three materials; resin which gives hardness, beeswax which supplies toughness, and tallow which renders the mixture soft enough to be worked up. The most common grafting-wax is made of four pounds of resin, two pounds of beeswax, and one pound of tallow.¹ The mixture may be varied to suit the need. In making the wax, the resin is crushed and melted slowly. Then the proper amounts of beeswax and tallow are added. The mixture is kept hot, but not boiling, stirred vigorously for some time, is finally dropped into cold water, and pulled like molasses candy with hands slightly greased. The wax can be applied to the grafts by being warmed and put on with a brush, or if of the proper consistency for the purpose, it may be put on cold with the hands.

Grafting-cloth is made by drawing strips of cloth through melted grafting-wax. Grafting-string is prepared by soaking balls of string in hot grafting-wax.

In order to reduce the high cost of grafting-wax due to the expensiveness of beeswax, a number of substitutes have been tried. Asphaltum and paraffin mixtures have been used successfully.

EXERCISES

EXERCISE I.—Preparing grafting-wax.

Materials.—Resin; beeswax; tallow; small pail or tin can; twine; strips of old cloth.

Procedure.—Prepare grafting-wax, grafting-cloth, and grafting-twine in accordance with the directions given in Chapter V. (It is suggested that each student prepare his own wax, using a small quantity of each ingredient in the proper proportion.)

EXERCISE II.—Budding.

1. Budding in the laboratory.

Materials.—Small branches of willow; sharp knife; string for tying.

Procedure.—Willow twigs may be prepared for very early spring

¹ For other formulas, see pages 169 to 171 of Bailey's Nursery-Manual.

budding in the laboratory by placing them in boiling water for an hour or so and leaving them in water over night. On such prepared material practice shield-budding and some of the other forms, keeping in mind the essential points necessary for successful budding. Write an account of what you did and illustrate with drawings.

2. Budding nursery stock.

Materials.—Young nursery trees; string; budding-knife.

Procedure.—Bud the trees according to methods described in the text. Keep a careful record of the growth of the buds. If nursery stock is not available, bud upon willow or other available trees.

EXERCISE III.—Practice in grafting.

1. Bench-grafting in the laboratory.

Materials.—Grafting-knife; one-year-old seedling roots of apple or pear (these may be obtained from nurseries); cions of last season's growth of apple or pear; waxed yarn for tying.

Procedure.—Make whip-grafts during the dormant season according to methods described in the text, grafting the cions desired on the roots. The roots may be cut from two to six inches long and the cion should

be long enough to make the total length of the graft of convenient length for planting later. Wind the grafts with waxed cotton yarn.

2. Cleft-grafting of nursery stock.

Materials.—Seedling nursery stock; grafting-wax; grafting-knife.

Procedure.—Cleft-graft the stock low down inserting the cion desired. Wax all cut surfaces thoroughly.

3. Top-grafting.

Materials.—Heavy grafting-knife or grafting-tool; worthless trees; mallet or heavy club; grafting-wax.

Procedure.—If some seedling or worthless trees four or more years old are available, top-graft them to desirable varieties according to methods described in this chapter. (Worthless trees in waste places are good for class practice in top-grafting.)

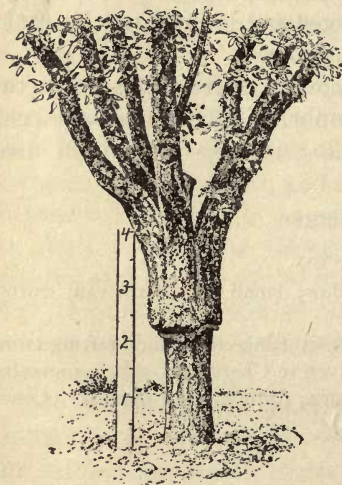


FIG. 61.—An uncongential graft union. The cion has grown much more rapidly than the stock.

EXERCISE IV.—Observation of budding and grafting methods, and of grafted and budded trees.

1. If there is a nursery in your section, visit it to see how grafting and budding are done.

2. Examine some grafted trees in your neighborhood. Notice the point at which the grafting or budding was done. Did a good or poor union result? Do the stock and cion appear to be growing at the same rate? In what varieties of grafted trees do you notice the cion to be larger than the stock or the reverse? How do you account for the difference in growth of the stock and cion? (See Fig. 61.)

CHAPTER VI

VEGETABLE-GROWING

IN THE growing of vegetables on a commercial scale, care must be observed to secure a location suitable for the production of the particular kind or kinds desired. However, closeness to market must also be taken into account, so that sometimes the proximity of a tract of land to markets will justify the expenditure of relatively large amounts for the upbuilding of the soil and for rents. In the home-garden many varieties of vegetables are desired, and the choice of soil is limited to the best available on the home place. Two facts, however, aid the home-gardener; first, that in almost any type of soil some vegetables can be grown; and secondly, that with patience and with a small outlay of capital small tracts of soil can be modified to almost any extent. Even the rigors of climate can be guarded against by the use of various devices. Shingles, lamp-shades, pieces of tin, paper bags, glass panes, hotbeds, coldframes, and many other articles, may become useful tools in the hands of the ingenious.

No activity will give more play to the ingenuity of a high-school pupil than the raising of a properly varied home-garden. In many cases, such enterprise will repay him handsomely. At any rate, the satisfaction to be derived from the presence on the family table of fresh vegetables of worthy quality is no inconsiderable reward.

138. The soil.—In general, a rich mellow sandy loam is preferable for vegetable-growing, and is especially desirable for root-crops. A sandy loam is easily worked, allows roots to penetrate, favors good drainage, and warms up well in the spring. A heavy clay soil is colder in the spring than a

sandy one and is, therefore, not so good for early vegetables. It puddles (sticks together) when wet so that air does not enter freely, and tends to bake and crack when drying. On the other hand, clay soils hold moisture in times of drought better than sandy soils. The addition of organic matter greatly improves either a sandy or clay soil. Organic matter may be added by plowing under green-crops, or by applying manure. If well-rotted stable manure is worked thoroughly into the ground in the fall, the soil will be in good condition in the spring. Poultry and sheep manures are very rich in nitrogen and must be used in small quantities only. Their use gives a luxuriant growth of stem and foliage. If the soil is acid in nature, the addition of lime will remedy the defect.

139. Plowing.—It is advisable to plow or spade deeply for the growing of vegetables. Fall plowing is useful as it leaves the ground loose and exposed to frost and weather action, and brings insects to the surface to be destroyed by the cold. Soil plowed in the fall absorbs rains readily. Fall plowing eliminates the necessity of working the soil deeply in the spring when weather conditions may render clays in poor condition for working.

140. Ordering and growing seed.—Some gardeners prefer to grow their own seed, but this requires considerable care and attention. For the home-garden at least it is much cheaper to buy seeds, although the growing of seeds is very interesting. Many reliable firms grow seeds for sale. In buying, the grower should make sure that the seeds were produced by a reliable firm and that they are not old and lacking in vitality.¹

141. Planting.—Before seeds are planted, the soil should be pulverized thoroughly. For the home-garden the hand rake is a most useful implement. Most seed should be planted in parallel rows. The seed-beds may be raised, depressed, or on a level with the surrounding land, depending

¹ Tests for the viability of seeds are discussed in Chapter III.

on the soil, crop, and method of watering to be used. By means of a hoe or stick, a trench is made into which the seeds are dropped. Seeds may also be planted with a drill, a very rapid method. The depth of planting is important (see paragraph 68). Seeds sown in the spring in moist soil not likely to dry out quickly are planted less deeply than the same kinds of seed when sown later in the summer. In planting small beds it is convenient to stand on a board while making the trench and sowing and covering the seed. The edge of the board will serve also as a guide in making a straight trench. Where the rows are longer, a wire or cord, stretched between two stakes, will help the gardener to keep them straight. Light soils should be pressed down firmly over the seeds to keep them moist so they will germinate readily. The thickness for sowing seed varies with the variety and habit of growth of the plants. Seeds should be sown thickly if they are low in viability or if the weather and soil conditions are unfavorable.

142. Transplanting.—Seeds may be sown in the garden or in flats, or in hotbeds and later transplanted out-of-doors. Some plants, including the cabbage, do best when transplanted. Early kinds are obtained in this way as they may be started before it would be safe to grow them outside. Many times it is necessary to “harden off” the young plants by transferring them to coldframes before setting them out in the open. The same effect is obtained by moving the flats out-of-doors before the plants are transplanted to the garden.

143. Cultivating.—After the plants are up, frequent cultivation is necessary to keep down weeds and to conserve moisture. When the garden is large enough, this work should be done with the aid of a horse, but on small areas a hand cultivator on wheels is a time-saving device. A considerable amount of hand hoeing and weeding is also necessary in the vegetable-garden.

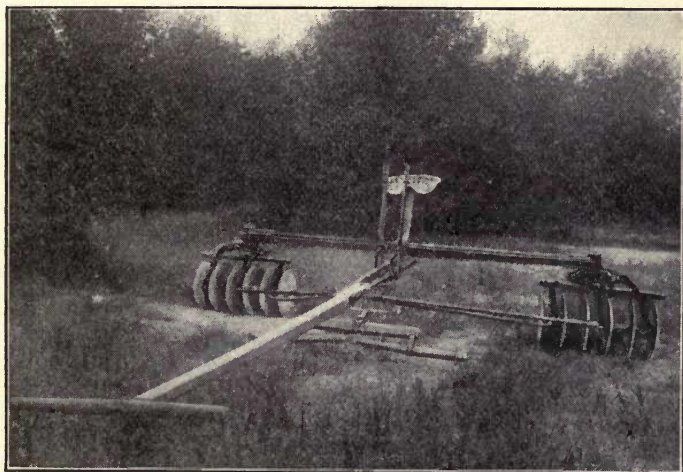


Plate III.—Upper: Planting a tree, using a planting-board. Lower: An extension disk, adapted to cultivation under branches.

144. Thinning.—Plants are thinned to give more space for growth. If just enough good viable seed is planted, no thinning is necessary; but it is advisable to plant an abundance of seed so that if the plants do not come up well or if cutworms or frosts kill part of them, there will still be a sufficient number. Any surplus may be thinned out later.

145. Watering.—The soil, if at all dry, must be moistened thoroughly as soon as the seeds are sown. Water should be applied freely to transplanted vegetables as soon as they are set. Thereafter a good soaking occasionally is better than light sprinkling often. After light sprinklings the water soon evaporates, with harmful rather than beneficial results. The watering-pot or hose may be used on small areas. A method of watering with overhead pipes known as the "Skinner system" is sometimes used, but is expensive. Irrigation by furrows is common. The raised-bed system (in which the bed is above the surrounding ground) is frequently employed and is adapted to rather heavy soils. Water is applied in ditches around the bed and soaks up into it. The depressed-bed system is adapted to rather light soils. Under this system the bed has a ridge of soil around it, and the water is carried along a ditch in the ridge on higher ground and soaks down into the bed.

146. Diseases and insects.—Sucking insects (for example, plant-lice) are killed with Black Leaf 40, a nicotine spray, or with other contact sprays. Biting insects (cutworms for example) are killed by poisons. Insects which work underground or at the surface like the cutworms, are especially difficult to destroy, since poisons sprayed on the plants cannot reach them. Late fall plowing helps to eliminate such insects by bringing the nests to the surface of the ground where they are destroyed by the winter's cold. Cutworms can be killed by putting poisoned bran on the ground close to the plant. The grubs usually prefer the bran to the plant. Sometimes pieces of tin or even thick paper may be placed around the

plant and down in the ground a short distance to prevent the cutworms from getting to the stem. Crop-rotation should be practiced where cutworms are present.¹

147. Tools.—Before beginning work in the garden, the necessary tools should be sharpened and otherwise made ready for immediate use. For a small garden, a spade, a rake, a hoe, and a hand-weeder may be all that is necessary, but for larger gardens the following list may prove suggestive: Wheelbarrow, mallet, stout cord, tape-line, stakes, tin-cans, hand cultivators, spading-fork, dibbers (Fig. 62) or trowels, sprinkling cans, hose, sprayers, wrenches, files, whetstone, and grindstone or emery wheel. Proper care will greatly



FIG. 62.—A
dibber.

prolong the life of implements. They should never be left out exposed to the weather. Paint should be applied to tools when needed. Tools should be cleaned of soil after each use.

148. Garden plans.—It is well to plan the garden and secure the necessary seed somewhat in advance of planting time. Plans should be drawn to scale, and should show each row of the particular vegetable to be grown. The plan should indicate the length of growing season of the different vegetables and the time of planting. Such facts may be obtained from seed catalogues.

With many kinds of vegetables (lettuce is a good example), all the seeds should not be sown at once, but small quantities should be planted from time to time throughout the growing season, that the supply of the vegetable may be continuous.

149. Classes of vegetables.—Vegetables may be classified according to the season favorable for their growth, as spring, summer, or fall vegetables. They may be classed as annual,

¹ Diseases and insects are treated more fully in later chapters.

biennial, and perennial. In the chapters following they are classified according to the parts used for food; namely those in which the underground parts are eaten, those in which the foliage and stems are used, and those in which the fruits are utilized.¹

¹ Exercises on vegetable-growing follow Chapter IX.

CHAPTER VII

ROOT, TUBER, AND BULB CROPS

Most root, tuber, and bulb crops grow best in sandy loam soils and in cool climates. A few, such as the sweet potato, require a warm growing season.

ROOT AND TUBER CROPS

150. The beet.—It is supposed that the modern cultivated varieties of edible beets were developed from the wild forms known to the ancients. Varieties are still found wild in the Mediterranean region. The sea beet, cultivated for its leaves, is a native of the seacoasts of England. The chard (Fig. 63), of which the leaves only are used as food, originated in Portugal, and was introduced into England as early as the seventeenth century. An ornamental sort, known as the Chilean beet, is said to have come from Chile in South America.



FIG. 63.—Chard beet.

Edible beets are cultivated to some extent in all parts of the United States and in many sections of Canada. They require a cool climate for the best development and are, therefore, grown extensively in the North. Beets grow best and have roots of most perfect shape in a rich sandy loam, although they can be raised with some suc-

cess on heavier soils. They respond readily to any well-balanced fertilizer containing potash, phosphoric acid, and nitrogen. If manure is applied to the soil in the same season in which the beet seed is sown, it should be well-rotted. Beets will not grow well on acid soils unless the latter are treated with lime. Seed can be sown early in the spring. Good sized tubers are secured in six to eight weeks. A continuous supply can be maintained by planting seed every few weeks throughout the growing season. The seed of the edible beet is really a fruit containing several seeds, so that a number of plants result from each fruit planted. For that reason, the seed should not be planted more closely together in the row than one to every inch or two. The rows may be from eighteen to twenty-four inches apart. After the beets come up, they should be thinned so that the roots do not touch one another. In commercial establishments, all the thinning is performed at one time. In the home-garden, thinning may be done from time to time and the discarded plants used for greens. The plants thinned from the row may be reset in new beds as they are easy to transplant. The culture of mangels, sugar-beets, and chard is practically the same as that of the table beet just considered.

151. The carrot.—The history of the carrot is not definitely known. The fact that the Dutch introduced it into England in Queen Elizabeth's time has led many to conclude that it was brought to its present stage of development in Holland. The carrot is grown over a wide area of the United States and Canada. The cultural directions are the same as for the beet, with the exception that the carrot will do well on poor soils. Seed may be sown early in the spring, or at any time throughout the summer, as carrots will stand heat well and mature in two or three months, depending on the varieties.

152. Celeriac, also called root-celery, is much like celery in appearance, but it is the root of the celeriac, rather than

the top, that is eaten. The roots may be boiled for a table vegetable, or used in salads and soups. Celeriac does best in a cool climate and in a rich soil. The seed is sown in flats or in the greenhouse and the young plants are usually transplanted once before they are finally set out in the field. Celeriac requires no blanching; otherwise its culture is the same as for celery (Fig. 64).

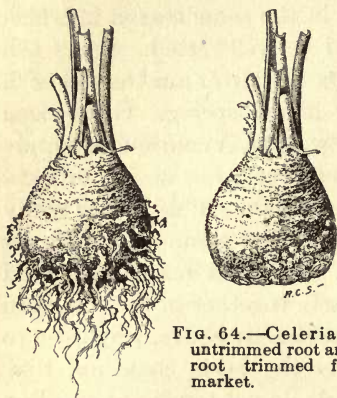


FIG. 64.—Celeriac, untrimmed root and root trimmed for market.

153. Chicory, which was used as a salad plant by the Greeks in early times, is found in a wild state in continental

Europe and in England. It is common along roadsides in the older settled regions of North America. It blooms in autumn profusely. Its flowers are of the brightest blue.

The roasted roots are employed as a substitute for coffee. Chicory roots (Fig. 65) are used as a table vegetable also. The tops are frequently cooked for greens, and when blanched are eaten as a salad. To produce the blanched leaves, the tops of the plants are cut off in the fall, and the roots are dug and replanted and then covered with several inches of soil. An abundance of blanched leaves is then produced. Seeds of chicory are sown early in the spring in much the same manner as carrot seeds.



FIG. 65.—Chicory root.



FIG. 66.—Root of horse-radish.

154. Horse-radish.—The root of this plant, ground and placed in vinegar, is used as a relish. Horse-radish is propagated by root-cuttings, the smaller branching roots being removed to furnish the cuttings at the time the larger roots are dug for market. Roots one-fourth or one-half inch in diameter are made into cuttings from four to six inches long, the upper end of the cutting being cut squarely across and the lower end slanting in order to indicate which end should be upward in planting. The cuttings are stored over winter in sand kept slightly moist, and are usually planted in the spring. In planting, the cuttings are set with the upper end just beneath the surface of the soil. A good loam, rich in humus, is best for horse-radish (Fig. 66).

155. Jerusalem artichoke is native to Canada and the northern part of the United States. Like those of the Irish potato, its tubers can be used as a table vegetable and in the making of soups and salads. The plant is a perennial, propagating itself from year to year. It grows well in poor sandy soils, but also responds to good soils. It is propagated by tuber-cuttings.

156. The parsnip is thought to be a native of Europe. It requires a long growing season, and for that reason the seed is sown in early spring. Parsnip seed produced the previous season should be sown, as older seed does not have power to germinate. Germination of even the best seed is slow. A deep loam is most suitable for the parsnip. The roots do not grow well in the hot summer months, but increase in size rapidly during the cooler autumn weather. The roots desired for winter use may be dug in the fall and stored, but as freezing improves rather than injures them, they are commonly left in the ground and are dug early in the spring when the ground has thawed out. The cultural directions for the parsnip are the same as for beets or carrots.

157. Irish potato.—The potato is a native of South America. De Candolle states that the Spaniards introduced it

into Europe at the beginning of the sixteenth century. It found its way from Spain to Italy, and from there it was carried to Belgium. It soon became common in central Europe. It is said that Sir Walter Raleigh took potatoes from America to the British Isles in 1585. Potatoes were soon grown to a considerable extent in Ireland, but were not introduced into Scotland until 1725. By 1750 the potato was grown extensively in nearly all parts of Europe.

While the greater part of the world's supply is produced in Europe, America ranks high in the production of potatoes. The potato is sixth in value among the crops cultivated in the United States, 40 per cent of the crop being produced in eleven states: namely, Maine, New York, New Jersey, Pennsylvania, Maryland, Virginia, Ohio, Michigan, Wisconsin, Minnesota, and California. Potato culture is the main horticultural industry of New Brunswick; it is important in British Columbia, and, is carried on extensively in the other vegetable-producing sections of the Dominion of Canada.

For planting it is important to select good medium-sized tubers free from disease. The tubers produce the new plants from the eyes or buds. It is common to cut the tubers in pieces of about two ounces in weight, each piece containing at least two eyes. The distal end of the potato (the end farthest from the point where it was attached to the parent plant) contains the best growing eyes. It is advisable, although not absolutely necessary, to cut the tuber so that one or more of the better growing eyes are on each piece.

If potatoes are stored in a warm cellar, they will produce long sprouts before planting time has arrived. This should be avoided by storage at a low temperature, since the removal of the sprouts lessens the vitality of the tuber. On the other hand, it is desirable to place the potatoes in a warm room for a few days before planting, since this will start the eyes into

growth and save time after the potato is in the ground. Another means of obtaining an early and rapid growth is by placing the tuber-cuttings in moist sand in a warm place until the tops are two or three inches high, when the plants are set out in the field. Such plants grow very rapidly during the first weeks and are much ahead of those resulting from tubers set in the ordinary way. In the northern states, the depth of planting should be about four inches. In the South, it should be greater, especially in light sandy soil.

Potatoes require a plentiful and even supply of moisture. Should the ground become dry when the plants are partly grown, the growth will be halted, and if it is started again by renewal of the water supply, gnarled and uneven tubers will result. This is one reason why the potato is planted deep. Cultivation to retain the moisture should be frequent. Irrigation is practiced in many of the dry sections of the country.

Potatoes require an abundance of plant-food. This may be supplied by plowing under a cover-crop, or by the application of manure, but the material should be thoroughly decayed before the potatoes are planted, since otherwise scab and similar diseases are likely to result. For this reason as well as others, it is advisable to rotate crops on potato land, the manure being applied to one of the other crops. If a commercial fertilizer is used, it should contain in most cases the three elements, nitrogen, phosphorus, and potassium. Frequently potassium is the element most needed.

Potatoes are dug by hand with a fork, or by a machine known as a potato-digger. They are then picked up and stored in cool dark cellars, or buried in pits at a depth sufficient to prevent freezing. Potatoes should not be allowed to stand in the light for any length of time.

The most common diseases of the potato are blight and scab. Blight may be controlled by spraying with bordeaux mixture at intervals during the growing season. Scab is kept

down by selecting smooth, clean, seed potatoes and soaking them a short time in a solution of formalin or corrosive sublimate.

The Colorado potato beetle is the most troublesome insect. It is controlled by spraying the plant with paris green or with other arsenical sprays. It is easy to kill the young larvæ soon after they hatch and begin feeding, but it is difficult to poison the old beetles.

158. The sweet potato constitutes an important crop in the southern states where the warm days and nights are especially suited to its growth. The plants are propagated in hotbeds and transplanted to the field. The thickened roots, commonly miscalled tubers, are placed just far enough apart in the hotbed to prevent their touching each other, and are covered with a few inches of sand. A large number of slips are produced by each potato. These slips are pulled up from the bed, while the parent potato remains in place to produce more slips. The slips are set out in the field, usually in ground that has been ridged.

Light sandy soils produce the best sweet potatoes. Good drainage is important. Moisture during the growing season is desirable, but too much moisture should be avoided when the roots are maturing. Frequently shallow cultivation should be given, and considerable hand hoeing is necessary.

The sweet potatoes are usually harvested by being loosened by means of a special plow and then pulled up and sorted by hand. They require different storage conditions than do Irish potatoes, a warm dry place being most suitable.

159. Radish.—It is probable that the original home of the radish was in western Asia and southern Europe. It was well known to the ancients. Radishes are mentioned in old Chinese books as early as 1100 B. C. Pliny gives interesting accounts of radishes grown in Rome. Several varieties were cultivated in England in Queen Elizabeth's time. Since then many varieties have been produced.

Light fertile soils are best for the radish. The seed is sown in rows. The small-growing varieties may be put rather close together in the row, but they should be thinned to give the plants enough space. In the home-garden, the radishes may be planted closely and thinned frequently, the roots removed in thinning being used on the table. Some of the small rapid-growing sorts mature from seed very quickly (in two or three weeks). Radishes must have plenty of moisture, as dry weather checks their growth, and pithy roots are the result. There are early sorts of radishes to be planted at the beginning of spring; summer varieties to be planted later; and still other kinds suited to producing fall crops. By planting the proper varieties at intervals, a continuous crop may be obtained for the table.

160. Turnips and rutabaga.—Although turnips will grow on almost any type of land, light soils produce those of best flavor. Seeds of the early sorts are sown as soon as spring opens. The later kinds are planted in the summer, maturing late in the fall, and are usually stored for winter use. The rutabaga requires a longer growing season than does the turnip. Both the turnip and rutabaga are cold climate plants and do well in the North. In climates having hot days and nights during the summer, these crops do not thrive, and the roots become stringy and bitter.

BULB CROPS

The edible bulb crops include a number of plants belonging to the onion family, such as onions, chives, leeks, shallots, and garlic.

161. Onion (Figs. 67, 68).—The origin of the onion, as is the case with many other plants cultivated from an early period, is somewhat obscure. The onion is mentioned in biblical literature, and is referred to in the inscriptions appearing upon the Egyptian pyramids. It is believed to be a

native of Asia. There are now many varieties of onions, differing in size, shape, color, and keeping qualities.

Like most bulbs, onions grow best in cool climates. They require an abundance of moisture, except at the time of ripening when dry weather is favorable. The largest onion-producing sections of the United States are in Massachusetts, New York, Ohio, Indiana, Illinois, and California. The onion is grown as a commercial crop to some extent in Canada.

A very rich soil containing an abundance of humus is necessary for the successful growing of onions. A good loam is to be preferred, although some varieties of onions grow well on muck lands. The addition of fresh manure should be avoided on account of the danger from the onion-maggot, a very troublesome pest. Well-rotted manure applied the previous fall is excellent. Onion land should be in cultivated crops two or three years before onions are planted in order that it may be as free as possible from weeds. It is very important that the seed-bed be finely pulverized. The seeds are sown in rows, about three seeds to the inch, and covered with about one-half inch of soil. The onion bed must be cultivated often and all weeds kept down. The plants should be thinned very early, and enough space left between them to prevent the bulbs from touching each other when full-grown. In the normal ripening process, the onions dry and shrivel at the neck first, and the leaves dry later. The onions are pulled and topped and then stored in a cool dry well-ventilated place.

Although the cheapest way to multiply onions is from seeds,



FIG. 67.—Onion in flower.



FIG. 68.—Top onion, one kind of "sets".

they are also propagated from sets, of which there are three kinds. Some varieties produce small bulbs on the top of the stalks (Fig. 68). In other varieties, small bulbs form from the division of the onion in the ground. These small bulbs may be planted the following season. This race is usually spoken of as the potato-onion or multiplier. The third and most common kind of "sets" used in propagating onions is produced by sowing onion seed very thickly. The resulting plants are so crowded that the bulbs remain very small. After they ripen in the fall, they are taken up and stored in the same way as bulbs of normal size. These small bulbs are planted in the spring and produce a very early crop of green onions. If left until fall, they are harvested as ripe onions. Another method of producing early onions consists in sowing seed under glass, and transplanting the young plants to the field.

The onion is not troubled with many pests. The onion-maggot is its worst foe. Rotation of crops is the best means of combating this enemy. The onion-thrips is troublesome in some sections. Spraying with kerosene emulsion is usually successful. The most troublesome disease is onion-smut. The best remedy is rotation of crops, but it is difficult to get rid of the disease. Soaking the seed for twenty minutes in a solution of one ounce of formalin to a gallon of water will prevent smut from being introduced from the seed. The seed should be dried before being planted.

162. Chives are perennial, growing year after year when once established. They are propagated in the spring by division (Fig. 69).

163. Garlic.—The bulbs of this plant are made up of a number of divisions known as cloves. Garlic is propagated by planting these cloves in early springtime. Garlic has an exceedingly strong flavor. It is not popular in this country except among foreigners, and is used in small quantities for flavoring.

164. The leek is mild in flavor. It is used principally for flavoring soups. Leeks are generally grown from seeds planted early in the spring. In the fall the plants are blanched by being banked with soil. The plants are usually

left in the ground until very late in the fall (Fig. 70).

165. The shallot produces a number of elongated bulbs, joined together at the base. It is propagated by separating and planting these bulbs in the early spring. The bulbs ripen in the fall



FIG. 69.—Chives.



FIG. 70.—Leek.

and may be stored in the same way as onions. In the southern states, shallots are frequently planted in the fall and are sold green in the winter when green onions are not in the market. The true shallot is apparently seldom grown, the plants known under that name being multiplier onions.

CHAPTER VIII

CROPS GROWN FOR FOLIAGE AND STEMS

CROPS grown for stems and foliage include members of the cabbage family, a number of plants used for greens, and several eaten as salads.

166. The cabbage.—The scrawny wild cabbage growing near the seacoast in England is probably the ancestor of the present-day sorts (Fig. 71). Improved varieties of cabbage were cultivated over 2000 years ago. The red cabbage has been grown extensively in Holland for hundreds of years, but never became popular in North America. The Savoy varies from the common cabbage in having wrinkled leaves (Fig. 72). As it is crisp, tender, and of a delicate flavor, it is one of the best cabbages for culinary purposes.



FIG. 71.—Wild cabbage plant in seed on chalk cliffs of England.

Cabbages are grown to a certain extent in nearly every part of North America, but the cool Great Lakes region of the United States and Canada leads in acreage. A deep well-drained, well-manured, rich loam is best for their growth. Clay subsoils near the surface are undesirable.

For early cabbages the plants are grown from seed sown under glass. The seedlings are hardened by being exposed to

the weather for a few days during the daytime after which they are set out in the open. For late cabbages, the seed is sown in beds prepared in the open, and the young plants are



FIG. 72.—The Savoy cabbage.

transplanted in the same way as are early cabbages. Late cabbages make much of their growth in the fall, while early cabbages grow in the spring and early summer.

The cabbage-worm is the pest most likely to cause trouble. It may be killed by spraying with arsenate of

lead or with paris green, but these poisons should not be used on the matured heads soon to be eaten. For this reason, hellebore is the substance employed after the heads of the cabbages have formed. It may be applied as a powder or mixed with water and used as a spray. The most common disease of cabbage is club-root. Rotation of crops is the best treatment.

167. **Brussels sprouts** probably originated in Belgium, and derived its name from the fact that it had been extensively cultivated near the city of Brussels. When the plant is young it resembles the ordinary cabbage, but as it gets older the stem elongates and bears buds, one or two inches in diameter, in the axils of the leaves. The buds are the parts eaten. On account of this method of bearing the buds, the plant is sometimes called the "bud-bearing" cabbage, although the heads of the common cabbages are also enlarged buds.

Brussels sprouts can be grown commercially only in cool climates. The same soil and culture is necessary as for the cabbage. The size of the buds is increased by cutting off the lower leaves along the stalk, allowing the leaves at the top

to remain (Fig. 73). The sprouts are said to be improved by freezing. Of all the plants belonging to the cabbage family, Brussels sprouts has the most delicate flavor.

168. Collards and kales.—These plants do not form heads as do cabbages. The leaves are the parts eaten. As collards and kales stand heat quite well, they are grown for the most part in the South where cabbages do not thrive. Their culture is the same as for cabbages. (Fig. 74).



FIG. 73.—Brussels sprouts.

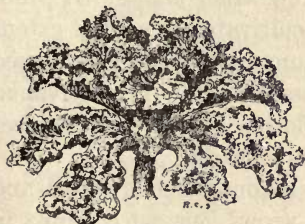


FIG. 74.—Kale.

169. Cauliflower.—Italy is perhaps the original home of the cauliflower, or at least of branching broccoli which is related to it. In 1600 it was grown in England to a slight extent, but by 1700 it was produced extensively for market. Both the English and the Dutch have improved the plant remarkably.

The cauliflower forms a head consisting of flowers and flower-stems (Fig. 75), differing in that respect from the cabbage in which the head is a single leaf-bud. The cauliflower is propagated and cultivated in much the same way as the cabbage, but special attention is given the hardening of the young plants before they are transplanted. The cauliflower is more exacting than the cabbage as to climate. It thrives in cool climates near bodies of water. Cool nights are necessary.



FIG. 75.—Head of cauliflower.

It can be grown successfully as a winter crop in the South. When the head begins to form, the leaves of the plant are brought together around the head and tied to protect the flowers from sunburn and to keep the head light in color. When the heads are fully formed, they remain in best condition only a few days, and must be harvested promptly.

170. Spinach.—Among plants used for greens, spinach easily takes the lead. Spinach requires cool weather, a rich soil and plenty of water. In the South it may be planted in the fall and grown as a winter crop, but in the North it is usually planted in the spring. It may be harvested as soon as the leaves attain sufficient size for handling.

171. Other plants used for greens are sea-kale, beets, chard, dandelion, and mustard. Some of these grow wild in profusion, but they are much larger when cultivated.

172. Celery is one of the leading salad plants. It probably originated in England. It is cultivated to a great extent in Europe and America. A large amount of celery is produced in the states of New York, Massachusetts, Pennsylvania, Michigan, Ohio, California, and Florida, and in the provinces of Ontario and British Columbia in Canada.

Celery requires a cool climate, an abundance of water, and a soil rich in organic matter. It grows very successfully in muck soil. Celery seeds are usually sown in flats, and covered very lightly with soil. A few days after the seedlings appear, they are removed to other flats in order to give each plant more space. In about three months, they are transplanted from the flats into the field. Early celery is set out in the spring. For a late crop, celery is planted in summer. In any case, the celery must be blanched. With the early crop this is usually accomplished by means of boards placed on both sides of the row to shade the plants. The late crop is blanched by piling up soil around the plant, leaving only the top leaves exposed (Fig. 76). Another system of blanching celery consists in setting it so closely that the tops shade

one another. This is practiced only in exceedingly rich ground.

173. Cress is sometimes called pepper-grass on account of its pungency. Cress is easy to grow. The seed is sown in the open ground, and the plant is ready for use in about six weeks. It runs to seed rapidly in hot weather. For a continuous supply, the seed can be sown every two weeks. Cress needs a plentiful supply of moisture.



FIG. 76.—Celery banked with earth.

174. Endive (Fig. 77).

—This salad plant is grown from seed planted in June or July. It must be blanched since otherwise the leaves are tough and bitter. The blanching is done by drawing the leaves together and tying them at the top. Endive should be used soon after blanching as the inner leaves rot if left too long.



FIG. 77.—Endive.

175. Lettuce.—This widely grown salad plant thrives on many types of soils. Cool weather and plenty of moisture are favorable for its growth, although much depends on the selection of varieties.

There are several types of lettuce; namely, leaf (Fig. 78),

head (Fig. 79), and cos. Leaf lettuce is the most easily grown. The seed may be planted in the greenhouse, or under glass, or may be sown out-of-doors. The lettuce is ready for use

within a few weeks. Head lettuce is considered more desir-



FIG. 78.—Leaf type of lettuce.

able. It cannot be grown well under glass since it is subject to rot. As head lettuce takes long to mature, the seed is sown in flats, and the plants are trans-

planted to other flats or pots soon after they come through the ground. They are hardened in the coldframe for a week or two before being transferred to the garden. Head lettuce should be thinned. In some varieties the heads grow to be a foot in diameter. Thorough and frequent cultivation conserves the moisture. Cos lettuce, the leaves of which do not form a compact head, is grown in the same manner as head lettuce, but some varieties require blanching of the inner leaves. This is accomplished by tying the leaves together at the top.

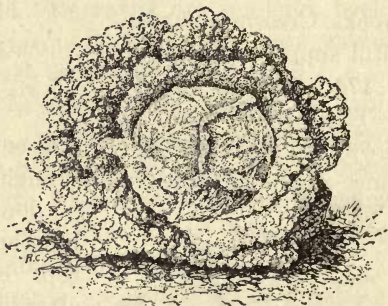


FIG. 79.—Head type of lettuce.

176. Parsley is able to withstand hot dry weather. Sometimes the plants are started under glass, but they are hardy and seed may be sown out-of-doors early in the spring in a carefully prepared seed-bed. As only a portion of the plant is picked at a time, a few individuals will furnish a continuous supply for the average family. Parsley is frequently transplanted to window-boxes in the fall where it will supply foliage all winter.

CHAPTER IX

CROPS GROWN FOR FRUIT OR SEED PARTS

THREE families of plants furnish most of the vegetable crops grown for fruit or seed parts—the legumes, nightshade family, and cucurbits.

177. The legumes.—The pea and bean are members of a large group of plants called legumes which bear their seed in pods. Other examples are the peanut, locust, clover, alfalfa, lupine, vetch, and acacia. The flowers of most of the genera possess the peculiar structure so familiar in the sweet pea. On the roots of legumes are tubercles containing bacteria which take the nitrogen from the air and fix it in the form of compounds available for plant use. On this account, the legumes can be grown in soil deficient in nitrogen. For the same reason, they are valuable crops for building up the soil, and should occupy an important place in plans for rotation. There are many different species in the family, yielding diverse and important products, as forage, hay, dye-stuffs, balsam, rubber, and oils; but the two garden plants of most importance are the pea and bean.

178. The bean was supposed to have come originally from Egypt, for there is mention of it in the early records of the Egyptian priests; but it grows wild in the tropics of both the Old and the New World, and forms differing from one another but little have been obtained from countries widely separated geographically. Since it is tropical, it will endure very little frost; and must be planted and harvested between the times of spring and autumn cold. The “bush” or dwarf forms have resulted from breeding and selection; the wild kinds are of the trailing or climbing type.

The bean thrives in warm weather, and will grow on almost any type of soil. Loose friable soils are most favorable. The seeds may be planted as soon as warm weather begins. After the plants are up, frequent cultivation is necessary. The dwarf kinds need no support but the climbing varieties or pole-beans should have some support for the vines.

There are many varieties of beans. Certain kinds producing pods free from fibers are used as string beans before the seeds mature. The pods of string beans are either green or yellow, the yellow ones being known as wax beans. Successive crops of string beans may be secured by planting every two weeks. Dry beans are planted in the same manner as string beans. They are left on the vine until the pod is ripe, when they are either pulled up by hand or harvested by machinery. Later they are threshed. The lima-bean plant produces large flat beans. It requires a warm temperature for growth and a better soil than most of the others.

179. The pea was known to the Greeks and probably also to the peoples of India and China. Davenport states that a small-seeded variety has been found in the ruins of ancient lake dwellings of Switzerland and Savoy.¹ It grew wild in its original form in the countries bordering the Mediterranean, and possibly also in the south of Russia. The present cultivated pea seems to be of comparatively recent development.

Peas require cooler weather than beans. They are, therefore, grown earlier in the spring. They are used both green and dry. There are dwarf, medium, and tall sorts. Their culture is similar to that of the bean.

180. The soybean (Fig. 80) and cowpea are cultivated in some countries for human food; they are used in North America for stock only, despite the fact that they are fully

¹ Domesticated Animals and Plants, Davenport.

as nutritious as the closely related garden forms. In this connection, Davenport says: "Man has a strange aversion to consuming the same grain he feeds his stock, and he positively refuses to eat it if it be a recent importation. The first question asked of a new food plant is this: 'Is it for man or animal?' without thinking it may be good for both; but the question once answered, the future of the thing is settled. This is why all efforts to introduce Indian corn into Europe to replace rye as human food have failed in the past and are likely to continue to fail in the future. Even the pauper resists what he considers to be putting him on a level with the animals."

181. The eggplant (Fig. 81) belongs to another group, known as solanaceous plants, which includes also the pepper and tomato. It requires a semi-tropical climate, thriving well in the southern part of the United States. It does not flourish with certainty where the nights are cool or the summers short. When grown in the North, it is started in the greenhouse and repotted several times before being transplanted out-of-doors after the warm season is well under way. The eggplant requires a rich soil. When once established, it can withstand rather severe drought. Its worst insect enemy is the Colorado potato beetle. Paris green applied as a spray is the common remedy.



FIG. 80.—The soybean.



FIG. 81.—Eggplant.

182. Red peppers (Fig. 82) are used either green or ripe.



FIG. 82.—Pepper.

The larger kinds are preferred for table use, while the smaller more pungent varieties are used for pickling and flavoring. Peppers are hardy and easily grown. Their culture is similar to that of the eggplant.

183. The tomato (Fig. 83) is native to America, its original home being in Peru. It was introduced into Great Britain in the latter part of the sixteenth century, but was grown at first only as an ornamental plant and

for medicinal purposes. Italy was first to recognize its value as an edible fruit. Later France and England used it for food extensively.

Tomatoes are grown out-of-doors in nearly all parts of the United States and Canada. In the extreme North where the summers are too short to insure the ripening of the fruit, the tomato is not grown commercially. Tomatoes are produced commercially in the South, in the middle states, and in some of the western states, especially California. Florida supplies the winter market.

As the tomato requires warm weather and a long season, in the North the plants are first grown from seed planted in hotbeds or in flats in the greenhouse. The seedlings are transplanted



FIG. 83.—Tomato trained on a stake.

to other flats and are later "hardened off" in coldframes or in the open. Finally when two or three months old, the plants are transplanted to the field. In warmer parts of the country, the seeds are sown in flats and the seedlings transferred to the open as soon as they can be safe from frosts. If planted deeply they resist drought well, because of the number of roots formed and the depth to which the lower roots reach.

The tomato frequently tends to grow branches and foliage at the expense of the fruit. This may be prevented by pinching off the terminal bud of the main stem and by limiting the supply of water. To secure the best results, the plants should be grown slowly, but should not be checked too suddenly in their growth. The vines are frequently tied to stakes to keep the fruit off the ground and prevent decay. Tomato plants are sometimes pruned to single stems. Such individuals yield larger fruit and mature earlier than if allowed to grow in their natural manner.

Young tomato plants are frequently troubled with cutworms. Paper collars placed in the soil prevent the cutworms from obtaining access to the plants at the surface. Poisoned bran mash is also a good means of control. The most troublesome disease is the fusarium-wilt. The remedy is rotation of crops. It is also important that the soil be changed from year to year in the flats in which the young plants are grown, as the continuous use of the same soil is likely to spread the disease.

184. Cucurbitous crops include cucumbers, gherkins, melons, pumpkins, squashes, and the like. All require a warm climate and are easily injured by frost.

185. Cucumbers are used in the green state, for immediate consumption or for pickling. When too ripe for these purposes, they are edible when cooked. They require an abundance of moisture. They are commonly grown from seed, and are planted in hills about four feet apart, in rows six feet apart. The vines cover so much ground that care should be

taken not to plant them too closely. For very early crops the seeds are grown under glass and seedlings transplanted to the field as soon as the temperature and the state of the soil will permit.

The striped cucumber beetle is the worst enemy of the vine and is difficult to control. Paris green applied as a spray is of value. Ashes, powdered lime, and powdered tobacco are recommended as repellents. Lice on cucumbers can be controlled by applying a nicotine spray.

186. Muskmelons may be either green- or yellow-fleshed. The former usually have an excellent flavor. Muskmelons will grow on many types of soil, but it should be rich in plant-food. They are very susceptible to changes in the moisture supply, and therefore, should be grown only on well-drained land.

Muskmelons are grown from seed usually planted in hills in the field after the weather has become warm. In planting the hills, it is customary to place some manure in the bottom of the hole and to mix it thoroughly with soil. Then more soil is added till the hole is filled. The seeds are planted near the surface with several inches of earth between them and the manure. A number of seeds are planted in each hill, but the seedlings must be thinned out to two or three. The distance apart of hills and rows should not be less than for cucumbers. Frequent cultivation of the young plants is essential.

Muskmelons do not stand transplanting well, but in the North, in order to secure early crops, they are frequently started in paper frames or little wooden boxes. Later the box, soil, and plant are set out in the ground intact.

187. Watermelons are usually grown on light sandy land. They need a warm climate, and should not be planted on the same piece of ground year after year. In the North only the early ripening varieties mature. The culture of watermelons is similar to that of muskmelons.

188. Pumpkins and squashes.—Field pumpkins (Fig. 84) are grown for stock-feeding, frequently in the corn field. Pie pumpkins are varieties having a superior flavor. There are several types of squashes, such as the Summer, the Hubbard, and the Crookneck. While pumpkin and squash vines will stand more frost than some other cucurbits, they are easily injured by low temperatures. The culture of pumpkins and squashes is similar to that of other cucurbits; they are easily grown.



FIG. 84.—Field pumpkin.

EXERCISES FOR CHAPTERS VI-IX

EXERCISE I.—Study of seed catalogues to observe what kinds of information can be obtained from them.

Materials.—Seed catalogues.

Procedure.—Secure seed catalogues from a number of seed houses and study them. Make a list of vegetables which could be grown in your home-garden. Make a planting calendar for these, giving time of planting and time of harvesting each kind of vegetable. Tabulate any cultural directions you can find for growing these vegetables.

EXERCISE II.—The plan of the home-garden.

Materials.—Large sheet of drawing paper; ruler; T-square; triangle; drawing board.

Procedure.—Draw a plan to scale for the home-garden as you intend to plant it. Show the rows of the respective vegetables, their lengths, distances apart, and the like.

EXERCISE III.—Careful study of a few vegetables.

Materials.—Plants grown in the garden.

Procedure.—Study in the home-garden the growth of a few plants from the time the seed is sown until the plant is mature. For example, grow onions in three ways: (1) from seed for the sake of obtaining ripe onions; (2) from seed for the purpose of obtaining sets for the next year's planting; (3) from sets. Give a report of your results to the class.

EXERCISE IV.—Transplanting vegetables.

Materials.—Vegetable seeds; flats of soil in which to grow seed; beds in which to set out plants.

Procedure.—Grow from seed a number of plants suitable for transplanting. Transplant some and care for them until they are mature. Transplant others two weeks later. Let some grow to maturity without transplanting. Let your cultural treatments of all be the same. Compare the results and report on them to the class.

EXERCISE V.—A study of the market prices of vegetables.

Materials.—Daily newspapers containing market reports.

Procedure.—Let the class study the movement of vegetables in the market by the following method. Each student should follow the price reported for some one vegetable and record it each day on a wall chart kept in the schoolroom for the purpose. As new vegetables appear in the reports, the task of following them should be assigned to members of the class, so that the records of the vegetable market will be complete. Newspaper comment on the reasons for the condition of the market should be brought to class and read. A new chart should be provided each month and the old ones preserved so that comparisons can be made. The exercise should be continued for at least four months.

EXERCISE VI.—Projects. Every student should have at least a small vegetable project. If he does not have a varied home-garden, he should decide on some one vegetable crop to grow, should secure all the information possible in regard to it from as many sources as are at hand; and should endeavor to make a financial success of the undertaking. He should prepare the soil, plant the seed, take care of the plants to maturity, and keep an accurate record of the costs, hours of labor, yields, selling prices, profit or loss, and so on. At the completion of the project, the student should hand in a careful account of the whole undertaking.

Many vegetable plants are grown first in the greenhouse or hotbed, and transplanted later to the field. When this is done the school should, if possible, coöperate with the student by furnishing facilities for raising the plants in large quantities so that they may be available for use in the student's own garden later. Provision should be made for raising at least the following plants in the school greenhouse or hotbeds: tomato, sweet potato, cabbage, cauliflower, eggplant, and pepper. When the school has no greenhouse, students may well exercise their ingenuity in improvising hotbeds and other substitutes. Small boxes covered by panes of glass and set indoors at night are useful.

CHAPTER X

ORCHARD MANAGEMENT

THE growing of fruit-trees on a commercial scale should be attempted only in favorable localities. Many kinds of fruit can be produced in the home orchard under adverse conditions by giving each kind such special attention as could not be done profitably in the commercial orchard.

189. Climate.—The climate of a region is the sum total of its weather conditions during a long period of time. Such factors are involved as heat, cold, humidity, dryness, winds, light, and sunshine. A newcomer in a section can determine the climate only with difficulty, for from the fruit-grower's standpoint a history of climatic conditions for only one year or two is not sufficient to tell the entire story. A tree is expected to thrive and bear fruit for many years.

190. Heat.—The source of heat is the sun. Since the atmosphere enables the earth to hold heat, its condition is a matter of importance to the horticulturist. A moist atmosphere is better for holding heat than a dry one. The density also makes a difference in the amount of heat the earth retains, as is shown by the fact that at high elevations less heat is retained than at low elevations where the atmosphere is more dense.

It is important to remember that each fruit requires a definite aggregate of heat units, during its growing season. Fruits differ greatly in this respect. For example, the date requires a large aggregate of heat units, and therefore thrives only in the hottest climates. The apple requires a very much smaller amount and hence it prospers in cold climates.

191. Cold.—Minimum winter temperatures and the lateness and severity of spring frosts are of such importance that they frequently govern the selection of the fruits to be grown. Frost control is possible only where the frosts are light and of short duration. Frost in spring injures the young growth, and when it occurs at blooming time and during the early setting of fruit, it may cause the loss of the entire crop. Still nights are conducive to frost, for if there is no wind the coldest air, being heaviest, settles down to the ground and so comes in contact with the vegetation. For the same reason, frosts are most severe on lowlands and in depressions, and lightest on slopes.

192. Moisture.—A certain amount of water is necessary for plant growth, and a large quantity is required for the “sizing up” and maturing of fruit. Old trees require much more moisture than young ones. It frequently happens that trees when young will thrive on the rainfall of a region, in which, when they become older, they will suffer from drought. Depth and character of soil affect the amount of moisture necessary. In loose soils of coarse texture, more rainfall is needed than is the case with soils of finer texture, which are more retentive of moisture. In humid countries it is important that the rainfall occur to a sufficient extent during the growing season. In semi-arid regions the time and distribution as well as the amount of the rainfall are important. For example, an amount of rain which would be sufficient if it fell during the fruiting season might be inadequate if distributed throughout the year. Irrigation makes it possible to grow fruit in very dry regions.

193. Air moisture.—Air is said to be saturated when it contains all the moisture it is capable of holding. Warm air can hold more moisture than cold air. Air blowing over large bodies of water or moist regions tends to collect moisture, while air moving over arid regions loses moisture. Humid air is favorable to the growth of most plants, but encourages

certain kinds of diseases such as brown-rot and bitter-rot. Water or vapor is more retentive of heat than is air. Therefore, when the air is dry, it cools rapidly after sundown. This is of great importance from a horticultural standpoint for it affects the aggregate of heat units available during a given period. It is also true that frost-injury is more common in dry weather than in wet or cloudy periods.

194. Winds.—Differences in the temperatures of bodies of air cause winds. Cold air, being heavier than warm, flows in and displaces it, causing air circulation. Winds may be helpful by keeping the air mixed so that frosts do not occur. Winds may be harmful, especially during winter, because when cold they have a drying influence. Winds sometimes do harm by breaking trees, especially when they are laden with snow and ice, by blowing fruit from the trees, and by causing light soils to drift.

195. Sunshine and light.—As explained in Chapter II, plants require light in order to manufacture food material. Different plants require various intensities of light. Some, such as orchard-grass, grow well in the shade, but most kinds require direct sunlight, especially for the production of fruit. Diffused sunlight, such as is present in cloudy weather, is not sufficient for fruit production. This is one reason why trees come into bearing quicker and ripen fruit faster in arid than in humid regions. It is a matter of interest that experiments have shown red light to be the best for plant growth, while violet light seems to give the best blooming conditions.

196. Soils.—Fruit-trees differ much as to the type of soil they require, but in general the soil should be well-drained, deep, and fairly retentive of moisture. There should be no hardpan near the surface for this prevents the roots from penetrating the soil, lessens the feeding area, hinders the absorption of rainfall, so that the surface soil may become waterlogged, and causes the trees to suffer in times of drought on account of the lack of a deep water-holding area.

Before planting, the orchardist should make sure that he has the type of soil suitable for the kinds of trees he desires to grow. Before buying land it is well to obtain the opinions of disinterested residents of the locality and also of the state experiment station as to the particular piece of soil. The depth and character of the soil can be ascertained by taking samples with a soil-auger. In new regions the vegetation is frequently a reliable index to the soil and climate. The presence of oaks, especially if they are large, indicates a good soil containing more or less clay. Pines indicate open, sandy, gravelly lands. Sometimes pines grow on almost sterile sand, as in Florida and on the sandy jack-pine lands of the North. When pine trees appear to be stunted, the land is very poor. Digger pines grow in the Sierras on land which is well adapted to fruit-growing. Walnuts, especially when of good size, are found on deep, loamy, well-drained soils containing a satisfactory amount of moisture. Willows indicate wet soils and frequently poor drainage. Sorrel (*Oxalis*) thrives in sour ground. *Ceanothus* frequently grows on land suited to fruit-culture. Its size and vigor tells the amount of rainfall. Sage-brush grows on arid land requiring irrigation if profitable crops are to be raised. When large in size, sage-brush indicates a deep soil, but if small and scrubby it signifies poor or shallow land. Such plants as grease-wood, saltworts, and samphires show the presence of alkali in the soil.

197. Selecting a location for the orchard.—The general location should be selected with reference to the climate, the soil, and the market. While nearness to market is an advantage, it is not so important a factor as it was years ago when shipping facilities were much poorer than they are today. After deciding on the general location, it is necessary to select the site for the orchard; that is, the particular part of the district, the exact place in the locality, or the exact spot of the farm upon which the orchard is to be placed. In selecting the site, it is necessary to consider the topography

with reference to elevation, exposure, rainfall, and nearness to bodies of water.

The actual elevation above sea-level influences the temperature and rainfall of a region. The elevation relative to the surrounding country determines the water and air drainage. Moderately elevated rolling lands are especially suited to fruit-growing because the cold air does not settle over the elevated portions, which as a consequence escape the frosts so likely to be present on the lower lands.

Exposure or aspect is the position with reference to the direction toward which the land slopes; for example, land sloping towards the north would be said to have a northern exposure. The best exposure depends on the location and the particular kind of fruit to be grown. In selecting an exposure, the presence or absence of large bodies of water is important. Water is an equalizer of temperature because it takes up and gives off heat more slowly than does the air, and, therefore, prevents frosts by warming the air. It is also a fact that in the spring the water may be cold enough to cool the air so that blossoming is retarded until danger of frost is over. To be effective, the amount of water must be considerable. The effect of a large expanse is seen in the case of Lake Michigan. Since the prevailing winds blow across the Lake from west to east, grapes and peaches can be grown commercially on certain parts of the land on the east side, while they cannot be grown successfully on the western shore. As the Finger Lakes in the state of New York are very deep, they are effective although small in size.

The following paragraph from Bailey's *Principles of Fruit-Growing* (20th and subsequent editions) includes some important facts regarding exposure as related to fruit production: "In locations adjoining bodies of water, the best slope is toward the water. . . . The particular direction of the slope in respect to the points of the compass is of a very secondary importance. There is often great choice between

the two sides of the river or small lake, particularly when the slopes are sharp and high. The side facing away from strong prevailing winds is usually preferable, particularly if the elevation back of it is sufficient to act as a windbreak. In interior or frosty regions, the best slope for the tender and early-blooming fruits, as a rule, is one that retards the blooming period, thereby causing the plant to remain comparatively dormant until the incidental spring frosts are passed. In such places, therefore, the northward and westward slopes are commonly most advisable; although, if these slopes are too pronounced, they may be so very cold and backward that what is gained by the retardation in spring may be lost by the retardation in fall, and the fruits may fail to ripen properly, or be caught by early fall frosts. . . . In regions in which there is much danger of sunscald on the trunk and larger branches, as in the midcontinental country and in hot arid areas, it is well to avoid pronounced southwestern exposures if possible. . . . If one desires to secure particularly early results and bright colors of fruits, a warm and sunny exposure, to the southward or southeastward, is most advisable. . . . It is sometimes necessary also, to study the exposure with reference to prevailing winds, when these winds are more or less constant and strong. The selection of the aspect may, in a large measure, obviate the necessity of establishing elaborate windbreaks."

198. Preparation of land for planting.—Before setting out an orchard on land previously untilled, it is well to grow a cultivated crop for at least a year. The land should be plowed deeply before the trees are planted. If it is to be irrigated, it should be leveled carefully.

199. Choosing the trees.—It is important that the young trees be chosen with great care. As the orchard is to be a long-time proposition, the grower cannot afford to take chances by buying from any but reliable nurserymen. If the local nurserymen can be depended on, it is well to buy from

them. The purchaser then has an opportunity to see the trees before he orders them. Furthermore, nurserymen are likely to feel more responsibility for trees to be planted in their own locality than for those to be shipped to a distance.

Trees which are true to variety must be obtained. It is very disappointing and expensive to purchase trees and care for them until they come into bearing and then learn that they are of some other variety than that desired. Trees should be of the proper size for the variety at the time of setting out. They should be of the correct age. The most satisfactory age for most varieties is one year from the bud or graft. Some growers prefer trees of certain varieties to be two years old. In any case, the older the tree the greater the shock in transplanting. The trees should be smooth and straight, with a good top and root system, and should be entirely free from disease or insect pests. The laws requiring trees sold or shipped to be inspected by competent commissioners have been of great service in preventing the spread of diseases and insects by the sale of nursery stock, but the grower should examine carefully all the trees he receives before they are planted.

200. Care of nursery stock.—After the trees are dug, the roots should not be allowed to become dry. Care should be taken in shipping and hauling not to expose the roots recklessly. It is seldom that the grower is ready to plant the trees as soon as they arrive. Immediately on receiving the trees, he should unpack them and “heel them in.” A trench is dug in a well-drained shady place, the roots are placed in it with the tops lying at an angle and the soil is then packed around the roots and the lower portion of the tops. This not only keeps the roots moist, but prevents the tops from starting prematurely.

201. Laying out and staking the orchard.—Whenever possible, the orchard should be laid out in rectangular form. Stakes are driven where the trees are to be placed, so that they

can be planted at a proper distance apart and in straight rows.¹

202. Orchard patterns.—There are three main systems in

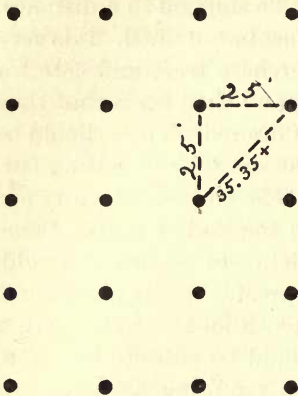


FIG. 85.—Square system of orchard planting.

common use in setting out an orchard; the square, quincunx, and the equilateral triangular.

In the square system (Fig. 85) the trees are planted at the corners of squares. It is the method in most common use and is the easiest one to lay out. A disadvantage of this arrangement is that the trees do not have an equal space in all direc-

tions for developing foliage and roots. It is probable that the roots use all of the area anyway, so the objection is not very important.

In the quincunx system (Fig. 86), a tree is set in the center of a square as well as at each corner. The fifth tree, the one in the center, is a "filler," one which will bear earlier than those planted at the corners of the square, and which will be removed when the other trees come

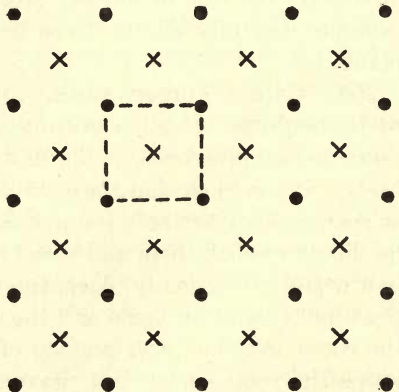


FIG. 86.—Quincunx system of orchard planting. Dots show permanent trees, crosses, fillers.

¹ For a complete discussion of this subject the student should see Bailey's *The Principles of Fruit-Growing*, pages 194 to 217.

into bearing. Peaches are frequently planted as fillers in apple orchards.

In the equilateral triangular system (Fig. 87), the trees have an equal distance for growth in all directions and are able to use all of the feeding area. This method is also known as the hexagonal, because the six trees surrounding one within form a six-sided figure as shown by the lines in the diagram.

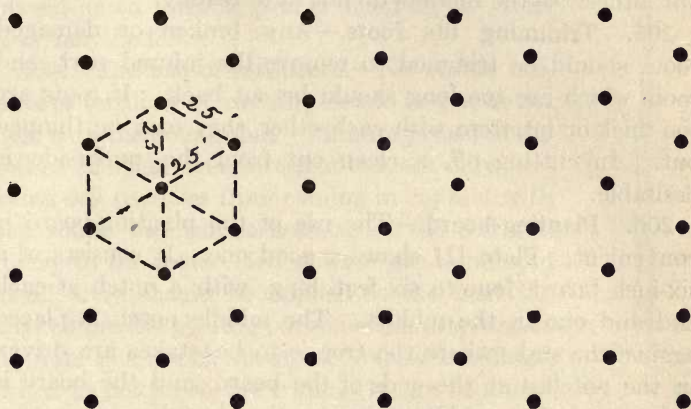


FIG. 87.—Hexagonal or equilateral triangular system of orchard planting.

Although it is a little more difficult to lay out an orchard by this system, the effort is replaced later on by the greater ease with which cultivating machinery, wagons, and the like, can be turned in the orchard.

203. Distance apart.—There is no rule to follow in regard to planting distance, since much depends on such factors as the habit of growth of the variety, the type of soil, and the amount of moisture available. Trees of upright form can be planted closer than those of spreading habit. Trees on rich deep soils should be placed farther apart than those on shallow or poor land, because on rich soils the trees grow larger. Trees should not be planted so close together that they do not have sufficient room for their normal development. An

individual should be wholly free from its neighbors so as to secure light.

204. Preparing the trees for planting.—When taken from the place where they are “heeled-in,” the trees can be hauled to the field in barrels containing water and planted at once. If they are not to be set immediately, it is well to place the roots in mud. It is important to keep the roots from drying out, otherwise the rootlets do not form readily.

205. Trimming the roots.—Any broken or damaged roots should be trimmed to remove the injured part, and roots which are too long should be cut back. If roots are too thick or interfere with each other, they may be thinned out. In cutting off, a clean cut from the underside is desirable.

206. Planting-board.—The use of the planting-board is convenient. Plate III shows a good one. It consists of a six-inch board, four to six feet long, with a notch at each end and one in the middle. The middle notch is placed against the stake where the tree is to be, stakes are driven in the notches at the ends of the board, and the board is removed. The middle stake can then be taken out in digging the hole. When the tree is to be set, the planting-board is placed with the notches at its ends against the two stakes, the tree is held in position at the center notch, and the hole is filled.

207. Planting the tree.—The hole should be of ample size to accommodate the root system, and should be dug only a short time before the tree is to be planted lest it dry out too much. With the planting-board in place, and the tree in position in the middle notch, the soil is worked in around the roots with the hands, while at the same time the tree is gently shaken up and down. Care should be taken to get the soil well worked in among and under the roots. The soil should be tramped firmly down after the roots are covered, and should be packed again after the hole is filled up. The tree

should be set at the same depth at which it grew in the nursery. If planted much deeper, especially in heavy soils, it is likely to die in the first season.

208. Pruning the top.—After the tree has been set out, it is customary to cut the top to a whip from eighteen to twenty-four inches high (Fig. 88), although if there are branches so placed as to form a proper head to the tree, they may be left.

209. The use of fertilizers.—No stable manure or fertilizer of any sort should be put in the hole with the young tree. Manure placed in the soil at the time trees are planted not only prevents soil particles from coming in contact with the roots, but causes heating of the soil and injury to the roots. If fertilizers are to be used at all, they should be applied to the land the year before the planting, or sometime afterwards. Manure as a mulch about the tree is beneficial, if it does not touch the trunk. It can be added to the surface of the soil immediately after the tree is planted.



FIG. 88.—Showing tree cut back to whip after planting.

210. Care of the trees the first year.—There must be an abundance of moisture in the soil for the growth of the young tree. If the supply is scanty, water may be added artificially. Cultivation is necessary to keep down weeds and prevent surface evaporation. Insects must be destroyed if present, and fungous diseases may require attention.

211. Tillage of bearing orchards.—Tillage is necessary in the orchard to increase the water-holding capacity of the soil, to conserve the water supply, to assist chemical activities, to destroy weeds, and to break up the breeding places of insects. It is usually advisable to plow or disk deeply either in the fall or early in the spring so that the soil can readily absorb rains. During the summer frequent cultivation is

necessary to keep down weeds and to maintain a dust mulch, which acts as a blanket in conserving moisture.

212. Cover-crops.—The incorporation of organic matter in the soil to better its physical condition and to increase plant-food is desirable on nearly all land. Where it can be secured, there is nothing better than stable manure. When it cannot be obtained, the growing of cover-crops may take its place to a certain extent, especially if legumes are grown to add nitrogen to the soil. To be effective, the cover-crop should be plowed under to add organic matter. There must be an abundance of moisture in the soil in order that the cover-crop may not rob the trees of their moisture supply. A cover-crop must be of such nature that it will grow well during the time when water is plentiful, either in the rainy season or when irrigation water can be obtained. In many hot semi-arid regions, where water is too scarce to grow cover-crops, cultivation to conserve the moisture results in burning out of the humus in the top soil. For this there seems as yet to be no satisfactory solution.

213. Inter-cropping consists in growing a money crop between the trees before the latter come into profitable bearing. Whether or not the grower can afford to crop his orchard in this manner depends on the fertility of the land and the crops he can grow. The inter-crop should not come closer to the trees than six or eight feet in any instance. Some common inter-crops are peas, beans, and other legumes, potatoes, pumpkins, squashes, and strawberries. In irrigated sections, the inter-crops are sometimes over-irrigated at the expense of the trees.

214. Fertilizers.—Before taking up the subject of fertilizers for orchards, it will be necessary to consider fertilizers in general. It has been found by experiments that the plant-foods most likely to be lacking in the soil are nitrogen, phosphorus, and potassium. A commercial fertilizer contains some one or more of these elements in the form of a compound

available to the plant. There are various nitrogenous, phosphorous, and potassic fertilizers. A complete fertilizer is one carrying all of these three elements, but the term does not indicate that the elements are present in any definite proportion.

215. Nitrogen is usually the first of the three elements to be exhausted and is, therefore, one of the most important of the commercial fertilizers. A scarcity of nitrogen is accompanied by a dwarfed growth, while in the absence of this element plants will not grow at all. This has been proved by many unsuccessful efforts to raise crops under conditions where it was not possible for them to secure any nitrogen, though they could obtain the other plant-food elements. Nitrogen is especially important when the growth of plants is mostly above ground, as in the case of lettuce. When the growth is underground, however, as in the case of the potato, carrot, and the like, nitrogen must be used more sparingly.

216. Sources of nitrogen.—The simplest and cheapest method of supplying nitrogen to the soil is by the use of leguminous cover-crops. (A legume is a plant which bears pods, such as the pea, bean, alfalfa, clover, vetch.) These plants have on their roots small galls or nodules (Fig. 89), caused by bacteria. The bacteria take nitrogen from the air, and form compounds which are later transferred to the roots of the plants, and from them distributed throughout the plant tissue. When these legumes are plowed under, the nitrogen is plowed under with them, enriching the soil. Where water power is abundant and electricity is cheap, nitrogen for use in fertilizers is obtained from the air. In this process an electric spark causes nitrogen and oxygen in the air to unite chemically. At the same time, water dropping through



FIG. 89.—Nodules on roots of legume.

the air unites with this new compound to form nitric acid. The nitric acid is then brought in contact with lime and forms a compound of lime, nitrogen, and oxygen called calcium nitrate. This source of nitrogen is certain to become of great commercial importance as other sources fail.

Thousands of tons of sodium nitrate (Chile saltpeter) are imported to the United States yearly from Chile.

Slaughter-house by-products, such as dried blood and tankage, furnish nitrogen in large quantities. Analysis of dried blood shows it to contain from 12 to 14 per cent of nitrogen, almost as high a percentage as in nitrate of soda. It differs from the latter in being a little less rapid in its action as a fertilizer, an advantage in some cases and a disadvantage in others.

217. Nitrogen and cover-crops.—The nitrogen in the soil becomes available under ordinary methods of cultivation at the rate of about 2 per cent each year; that is, if an acre of land to a depth of one foot contains ten thousand pounds of nitrogen, cultivation will enable plants to utilize about two hundred pounds of it yearly. When the winter rains come, this available nitrogen, being soluble, may be washed out of the soil and lost. Especially is this true in sandy or gravelly land, particularly where the precipitation occurs as rain rather than as snow, and comes in large quantities at a time. Since nitrogen is one of the most expensive fertilizers, the loss of it in this way is a serious matter. To prevent this loss in climates sufficiently mild to permit it, winter cover-crops are planted. These take up some of the available nitrogen from the soil. In the spring after danger of washing is over, they are plowed under and the nitrates are then returned to the soil as the plants decay.

218. Nitrification.—The process that these decaying plants undergo is exceedingly complicated and interesting. The active agents are bacteria, which work in groups, each group acting on certain substances.

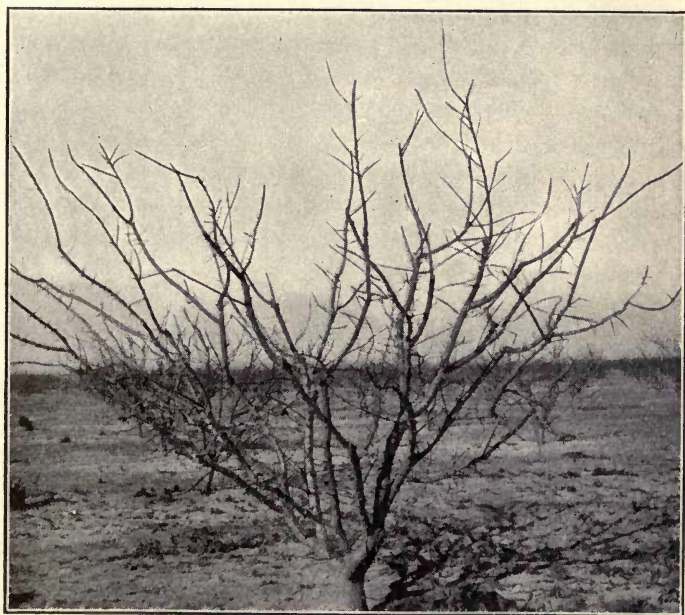
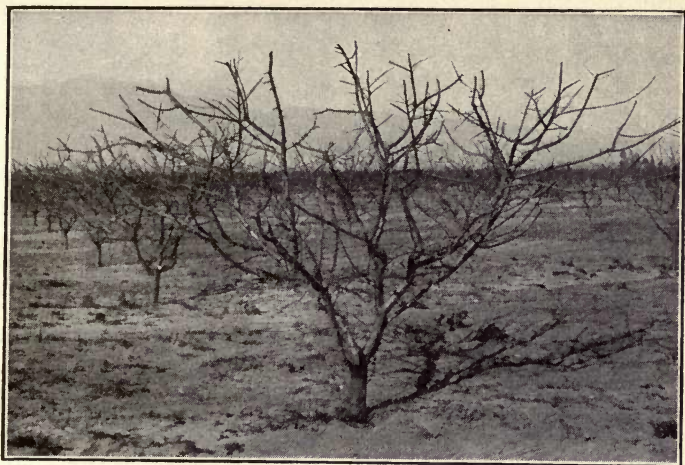


Plate IV.—Upper: A type of pruning known as “heading back severely.”
Lower: A tree pruned to laterals.

There are three stages in the process. In the first stage one set of bacteria causes the nitrogen and hydrogen in the decaying vegetable matter to unite, forming a compound called ammonia. Sometimes the odor of ammonia can be detected as it escapes into the air from decaying piles of moist leaves or manure. The ammonia that is escaping carries large quantities of nitrogen with it, for ammonia is by weight fourteen-seventeenths nitrogen. At the present price of this element, it is easy to see that escaping ammonia represents a very large financial loss.

After the ammonia is produced, other bacteria act on it, changing it to nitrous acid. Then the nitrous acid is acted on by still another set of bacteria, which change it into nitric acid. Nitric acid as it comes in contact with the soil unites with various compounds already there, forming soluble salts known as nitrates which are available for plant use. All the nitrogen which is "locked up" in organic matter must first go through this process before it can be used by the plant. Therefore, organic fertilizers which carry nitrogen, such as blood and tankage, are not immediately available to the plant, but must stay in the soil long enough for the nitrification process to take place. The nitrogen is then available.

219. Phosphorus is a yellowish semi-transparent substance. Because of its affinity for oxygen, it must be kept under water or oil; if exposed to the air for even a brief time, it forms a white smoke-like substance, a compound composed of oxygen and phosphorus (phosphorus pentoxide) which is heavier than air, and which dissolves in water, forming phosphoric acid. If introduced into the soil, it there unites with various soil substances, forming phosphates. Phosphates are among the most important plant-foods in the soil. The phosphorus used in fertilizers is derived principally from calcium phosphate and from ground bone. The former is a mineral occurring especially in Tennessee and South Carolina. It is mined, ground fine, and sold in this form as raw rock

phosphate; or it is treated with sulfuric acid to form a compound known as super-phosphate. Raw rock phosphate becomes available to plants very slowly, and there is little appreciable effect from it until after a period of years. Super-phosphate, on the other hand, dissolves readily, and becomes available to the plant at once. However, it is very much more expensive than raw rock phosphate. Ground bone is a by-product of the meat industry. Before being ground the bones are usually steamed in order to remove the substances used in the manufacture of gelatine and glue. This steaming process also dissolves out the fat, thus making the final product very much more desirable for fertilizing purposes; for if the fat is not removed, it forms a thin film about each particle of bone and so hinders the process of decay in the soil as to render the bone-meal practically useless for fertilizing purposes for a considerable period of time. The steaming process is of further benefit in that the application of heat hastens the breaking up of the phosphate compounds of the bone, thus making some of the phosphorus immediately available to the plant.

Phosphorus is also obtained from Thomas slag, a by-product in the refining of iron ore, containing from 15 to 20 per cent of phosphoric acid. It is ground to a fine powder before being used as a fertilizing material.

220. Potash.—A considerable portion of the potash used in the United States is imported from foreign countries, although mineral deposits have been found in this country. Potash is also secured as a by-product in the manufacture of cement. The dust from the mills is collected and treated in such a way as to extract the potassium compounds from it. This not only yields more than sufficient potassium sulfate to pay for the process, but also to a great extent eliminates the very considerable injury formerly done by the cement dust in killing plants growing in the vicinity.

Soils derived from a granite source are likely to be rich in

potash, for granite contains feldspar, a mineral which carries large quantities of potassium. As a rule, therefore, where soils have been derived from a nearby granite source, they contain an abundance of potash, and it is not necessary to add any in the form of fertilizer. On the other hand, swamp soils generally contain an abundance of organic matter and ample nitrogen, but are frequently so deficient in potassium that they are practically worthless until this element is added.

Potassium in the soil becomes available very slowly. In this it differs from nitrogen. It has already been stated that about 2 per cent of the total nitrogen content becomes available each year. Of the potassium in the soil, only about one-fourth of one per cent becomes available in any one year. Thus, the nitrogen becomes available approximately eight times as fast as the potassium. Phosphoric acid stands as regards availability about half way between these two.

One of the best methods whereby the amount of available potash and phosphoric acid can be increased is by the addition of organic matter. This is especially true in the regions of relatively small rainfall, where humus is already deficient. The raising of cover-crops and the plowing under of manure constitute the most rational processes of fertilization in these parts of the country.

221. Fertilizers for fruits.—In fruit-growing the use of fertilizers gives a better quality of fruit, a larger yield, and in orchards fertilized year after year, a longer period of profitable bearing. But fertilizers must be applied intelligently. The character of the soil, the nature of the crop, the prices of fertilizing materials, all must be taken into account. No specific recommendations can be made since each locality, and indeed each orchard, is a separate problem. There are a few general rules that it is well to keep in mind: (1) Nitrogen induces wood and leaf growth, and beyond a certain point these compete with fruit growth. (2) The most cheaply

available source of nitrogen is the atmosphere, the most efficient agent for its fixation in the soil being the bacteria which live on the roots of legumes. (3) Since the object in the use of fertilizers is to secure larger net financial returns, the process should never be carried to a point where increased yield is not sufficient to pay increased costs. (4) The state experiment stations have studied the problem of fertilizers for their own localities at first hand, and their publications will give valuable assistance to the orchardist.

222. Pruning methods vary somewhat for different species of trees, and sometimes for varieties within a species. They differ also in separate regions. It is not the purpose of this chapter to treat of all pruning systems, but of the principles which are generally applicable.¹

223. Pruning young trees.—As has been stated, when the young tree is removed from the nursery, a considerable loss of root results. On this account, at transplanting time or shortly thereafter, the top must be reduced to maintain a proper balance of the part above ground with the roots. At this time one must have in mind also the establishing of the permanent form of the tree. It is customary to cut the young tree back to a whip, with the top eighteen to twenty-four inches high (Fig. 88). However, when the young transplanted tree already has branches properly located on the trunk to form the scaffold branches they may be left and all others cut off.

In trees pruned to a whip after planting, it is advisable soon after growth starts in the spring or early summer to pinch out the terminal bud of all shoots except the ones desired for scaffold branches. The removing of the terminal buds in the undesirable shoots prevents their growth in length but allows the leaves already produced to remain for shading the trunk.

¹ For more complete information, the student should read such publications on pruning as Kain's *Pruning Book*, Bailey's *Pruning-Manual*, and the bulletins on pruning issued by the state experiment stations.

This also aids in forcing out the buds and branches desired for the framework of the tree. Usually three are left to form the main framework. They should be well distributed around the tree and should not be closer to each other than six or eight inches (Figs. 90-91).

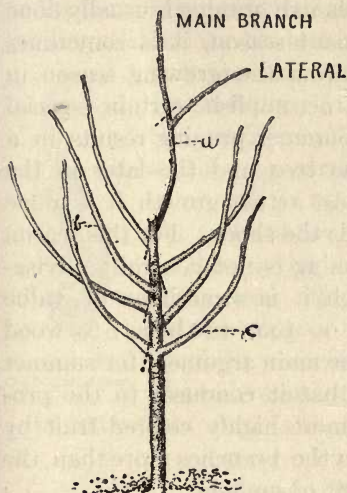


FIG. 90.—A one-year-old apple tree before pruning. The lines show where to cut. Three scaffold limbs, a, b, c, are left.

After the first growing season, in the dormant period, pruning is done to give the proper shape to the tree. The main branches previously selected to form the framework are allowed to remain, being headed back or cut to laterals (side branches). All other branches are removed.

In the second and third season, with few exceptions, it is

only necessary to thin out unnecessary branches or at most to cut to laterals. (See Plate IV.)

224. Pruning trees of bearing age.—Many trees, if properly pruned and in good soil, begin to bear fruit as early as the fourth season. Recent investigations have led to modifications in the older methods of pruning. In pruning bearing trees, it is advisable to thin out the branches to admit light and air, then fruit-spurs and fruit-buds usually develop in profusion. Cutting to laterals is also beneficial. Continual heavy heading back is not advisable, for it results in the growth of a large number of small shoots near the cut ends so that wood growth rather than the development of fruit-spurs and buds is the result, and the tree becomes very "bushy," requiring heavy pruning the following year. Sunburn is likely to occur after heavy heading. Branches may

well be headed back, however, to keep them within bounds and to give proper shape to the tree.

225. Summer pruning.—Although pruning is usually done in the dormant season, it is sometimes practiced during the growing season in summer to accomplish certain special purposes. Summer pruning results in a shock to the tree, and the later in the period of most active growth it is done the greater is the shock. For this reason summer pruning is not generally advisable, although it is sometimes of value in checking a too exuberant wood growth. The main argument for summer pruning is that it conduces to the production of more highly colored fruit by admitting to the branches more than the usual amount of sunlight.

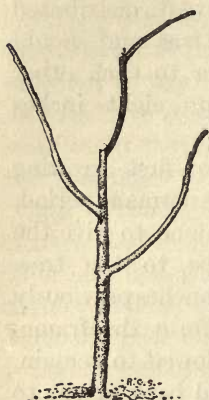


FIG. 91.—The apple tree in Fig. 90 after pruning.

226. Pruning tools.—Some good pruning saws and shears are illustrated in Figs. 92–97. Pruning tools must be strong and sharp. Long-handled shears should have a rather thin blade, a bar curved so as to hold the branch firmly while cutting, and should be so constructed that the blade has a slight “draw cut” as the handles are closed.



FIG. 92.—Pruning saw.

227. Making the cuts.—In pruning to a bud, the branch is cut off a short distance above the bud. In removing a side branch or a lateral, the cut should be made as close to the main branch as possible. By selecting a bud pointing in the right direction, branches may be so cut that the growth from the bud will take place in any direction desired. In this manner it is possible to spread close-growing trees, and to close up wide-spreading trees. In cutting off a branch to a

bud, the blade of the pruning shears should be next to the bud, and the bar away from the bud in order to avoid injury to the part of the branch remaining. In the same way, in removing a lateral the blade should be next to the branch which



FIG. 93.—Fold-
ing pruning saw.

is to remain, otherwise ragged wounds are left. Furthermore, if the hand-shears are not held in the position indicated, they will soon be sprung and become worthless. In removing side branches, care must be taken not to leave stubs, for these dry out and decay, thus afford-



FIG. 94.—Pruning saw.

ing opportunity for the entrance of disease. It should be remembered that cutting off a portion of a branch retards its growth in length and diameter.

In some trees wounds heal rapidly, in others very much more slowly. Wounds are exceedingly

slow to heal in the peach, but heal rapidly in the apple. It is advisable to paint over all large wounds, especially in trees slow to heal, with a protective mixture heavy enough to hold the moisture within the wound and prevent drying out and checking, and the consequent entrance of disease. White lead paint, asphaltum, and oronite are used successfully for this purpose.

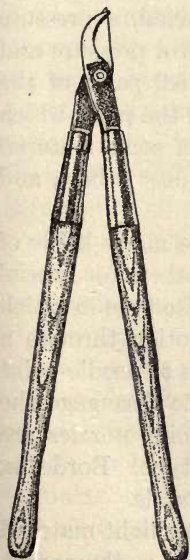


FIG. 95.—Pruning
shears.



FIG. 96.—Pruning
shears.

228. Spraying.—Spraying is one of the most necessary tasks the orchardist has to perform. To be successful he must



FIG. 97.—Pruning shears.

know what insects or diseases he is spraying for, and must apply the spray at the proper time and so that no parts of the tree are missed.

229. Spraying machinery.—Spraying machinery must be of such construction that the spray can be applied rapidly and effectively over the entire tree. There are many types of spray machines, such as hand sprayers for small plants or trees, knapsack sprayers for applying both liquid or dust preparations, bucket pumps and power outfits. The latter are the best for large orchards. A power outfit consists of a tank to hold the spray, a pump which should be able to keep up a high pressure, an engine for running the pump, an agitator for keeping the spray in the tank mixed, a pressure gauge and regulator for maintaining a uniform pressure and a truck on which the outfit is mounted. All parts of the outfit should be durable in construction, and the parts which come in contact with the spray should be of some material which does not corrode easily; for valves brass is best, and for the tank wood is generally used.

230. Nozzles and spray-rods.—There are many kinds of nozzles, some suited for general work and others for special purposes. One of the most common is the disc type in which the spray is forced out with a whirling motion through a small hole in a disc. There are many types of needle-point nozzles, in which a needle is so placed as to disengage the material when the nozzle clogs. Needle-point nozzles are now largely replaced with those of the disc type. Bordeaux nozzles are of value for spraying coarse materials.

A spray-rod consists of a hollow rod of some light material through which the liquid travels from the hose to the nozzle. The rods are of different lengths, depending on the size of

the trees to be sprayed. A comparatively recent invention, known as the spray-gun, is now rapidly replacing the spray-rod for most types of work. The spray-gun is a short rod equipped with apparatus to regulate the fineness of the spray and the height of the stream. It is light and easy to handle and permits of rapid and thorough work.

231. Kinds of sprays.—Sprays are of two sorts; liquid, and dust sprays, each of which has its advantages. Powder or dust sprays do not require elaborate machinery for their application, and can be used on fruits just before they ripen without injury, and may be applied when the ground is too soft to permit of the use of a heavy liquid spray outfit. On the other hand, liquid sprays can be applied more evenly and at a greater distance than dust sprays, adhere better, and can be used when there is considerable wind.

Sprays for fungous diseases are known as fungicides. Bordeaux mixture and lime-sulfur preparations are the commonest. Sprays applied for the purpose of combating insects are called insecticides. These comprise poisons for chewing insects, and contact sprays which kill the insects by corrosive action on the body or by stopping up the breathing pores. Paris green and arsenical poisons are examples of the former; kerosene or crude oil emulsions are examples of the latter. Some materials are used both as insecticides and as fungicides, as lime-sulfur solution. There is also the fumigation process in which gas is depended on for destruction of pests. Hydrocyanic acid gas and carbon bisulfide are much employed for this purpose.

Formulas for making various spray materials are well standardized. The student can obtain from the experiment station in his state definite information in regard to spray formulas, making spray mixtures, and applying sprays for the kinds of insects and diseases common to the section of the country in which he resides. There are also a number of good books on the subject.

232. Thinning the fruit.—When fruit-trees are allowed to bear too heavily, the fruits do not reach the proper size, and the value of the crop is lessened. Thinning of the fruit by hand is resorted to with plums, peaches, apples, and the like. Thinning should be done while the fruit is small, before it has had a chance to draw heavily on the tree for food and moisture supply.

233. The personal factor.—The success of orcharding depends largely on the personal interest of the owner. If he is willing to give his individual time and attention to the management of the orchard, rather than leave the matter to tenants, and has selected a suitable locality, his success is reasonably certain.

EXERCISES

EXERCISE I.—Laying out and staking an orchard.

Materials.—Stakes sharpened at one end; surveyor's chain, or wire, steel-tape or other tape measure; mallet for driving stakes.

Procedure.—Upon a vacant piece of ground lay out and stake orchards according to the three methods mentioned in this chapter. (Several students should work together.)

EXERCISE II.—Planting trees.

Materials.—Young trees for planting; planting-board; stakes; mallet; shovel or spade; tub of water in which to keep the roots of the trees moist until they are planted.

Procedure.—Prune the roots. Then plant the trees carefully following the essentials for success mentioned in the text. After the trees are set out, prune the tops in the manner suggested in the text.

EXERCISE III.—Observation of orchards in the locality.

Procedure.—1. Study different planting systems in your locality. How far are the trees apart? Are they far enough apart? 2. Notice good and poor orchards in your locality. State in what respects each of the following are responsible for the condition of the orchards examined: (a) climate, (b) location, (c) soils, (d) care.

EXERCISE IV.—Pruning studies and pruning of bearing trees.

Materials.—Pruning-shears, and saw; fruit-trees for the student to study and prune.

Procedure.—Study some bearing trees. How old are the trees? What kind are they? What variety? How can you distinguish fruit-buds from leaf-buds? How are the fruit-buds arranged with reference to the leaf-buds? Are the fruit-buds borne on spurs or on laterals? Upon wood of what age are they borne? How will this influence your pruning of trees this year? What facts enable you to tell by observation the amount of wood growth during each of the several past years? How many years' growth can you trace? State the objects to be attained in pruning these particular trees.

2. Prune one or more of the trees studied. Write a full account of your procedure. A brief description of the tree before and after pruning should be included in your written exercise. Special difficulties which you have encountered may be mentioned. Drawings or diagrams relative to the following should be included: (1) Drawing showing typical shape and relative size of fruit-buds as compared with leaf-buds. (2) Drawings showing position and arrangement of fruit-buds upon branches. (3) Diagrams or photographs showing typical shape and condition of trees before and after pruning. (4) Diagrams showing how to make the different cuts used in pruning.

EXERCISE V.—Study of spray-nozzles, guns, and spraying machinery.

Materials.—Spray-guns; nozzles; power spray outfits; tubs or pails; gallon measure; watch; wire screen in frame; long stick or hoe handles.

Procedure.—1. Study the construction of various spray-nozzles and spray-guns. Make diagrams of each type.

2. Perform the following tests on nozzles and spray-guns: (1) With the pump running so as to produce proper pressure, obtain the normal discharge a minute of each nozzle and gun by running water through the nozzle, collecting the spray in a tub or in pails and measuring the amounts. (2) Test the force of the spray from each nozzle and gun by measuring the distance the spray will reach. (3) Test the area the spray will cover by measuring the diameter of the area covered by the spray at the same distance from each nozzle. This may be ascertained by directing the spray on a fence or building. (4) Test the force of the spray from different nozzles by placing a wire screen in the path of the spray at a definite distance from the nozzles. Notice the distance the spray travels after passing through the screen. (5) Determine whether the spray comes out of the nozzle as a solid cone or as a hollow cone by putting a stick through the cone of spray. (6) Summarize the good and bad points of each spray-gun and nozzle.

CHAPTER XI

IRRIGATION AND DRAINAGE

THE records of irrigation practice extend far into the dim past of human affairs. Plato obtained from his ancestor Solon an account of a mythical island named Atlantis, situated in the Atlantic Ocean beyond the Pillars of Hercules (that is, the Straits of Gibraltar). In the account the island was described in great detail, the part of the description of special interest being that of the irrigation system, which was exceedingly complete in every detail. According to Plato's story, this account had been given to Solon by an Egyptian priest who stated that the fabled island in question existed 10,000 years before his time; and Solon lived 2,500 years ago!

We know, also, of extensive irrigation works among the Egyptians which were constructed at least twenty centuries before the Christian era. Indeed in Egypt today irrigation is practiced in ways that epitomize the achievements of hundreds of centuries, for land is watered by the slow and laborious process of lifting the water from the Nile with a well-sweep or shadoof, and it is also watered by means of great irrigation projects planned and constructed under the direction of the ablest irrigation engineers England could summon into her service.

In the Euphrates Valley in Asia are remnants of irrigation systems far antedating any in recorded history. These systems were, in many respects, elaborate and complete. They represented an immense amount of labor, together with a knowledge of engineering problems that we of this

day find difficult to ascribe to so remote a civilization. Cities were built up and entire areas developed, whose inhabitants relied solely for subsistence on these irrigation works. The remains of these ancient systems can still be traced in sufficient detail to give an idea of their extensiveness and efficiency.

In America irrigation was practiced by some Indian tribes (or nations) long before the earliest white man set foot on the continent. In parts of New Mexico there remain to the present day irrigation systems which are abundant testimony to the skill and foresight of these inhabitants. Canals still in a fair degree of preservation extend many miles around and across plateaus, connecting the sources of water with the places where it was to be applied. For designing works of this sort, these aborigines possessed no instruments such as we have today for the making of precise measurements. They adopted the device of filling the ditches with water as they dug, being guided in this way as to the route which the canal was to follow. The results were ditches of marvelously even grade.

234. Recent irrigation.—Irrigation in America under the regime of the white man may be said to have begun with the Mormon settlement of Utah. Smythe, in his book *The Conquest of Arid America*, gives an exceedingly interesting account of the way in which these Mormon wanderers reclaimed an unpromising desert and made of it one of the most fertile regions of the United States. For a full account of this pioneer effort in irrigation, the student is referred to Smythe's book.

235. Reclamation service.—In 1912, during the presidency of Theodore Roosevelt, the United States Government for the first time definitely adopted the great policy which led to the establishment of the Reclamation Service. Briefly stated, it was this: The Government stands ready to finance and execute projects in irrigation and drainage which in the

judgment of its engineers are practicable and which on account of the time and money involved would be out of the question for private capital. Along these lines some notable undertakings have been carried to completion. The immense amounts of money and the engineering skill required were not available to any individual or the ordinary corporation, and the Reclamation Service performed a task which otherwise would perforce have gone undone. How great have been the benefits the following statistics will abundantly show. At the beginning of the year 1920 a total area of 18,191,716 acres had been put under irrigation. The value of products obtained from these farms in 1919 reached the vast total of \$801,005,326.

236. Irrigation in humid regions.—In one sense, and especially in some localities, irrigation is a form of insurance. Rainfall may be abundant, if the total annual precipitation is taken into account. But it may be lacking at those times when it is most critically needed; and an irrigation plant would justify itself even though it might be used only at long intervals. It is on this basis that provision for irrigation has been made on many farms in the humid sections of the United States.

237. Sources of water.—Water may be secured from mountain streams by the simple process of diversion to canals; or it may be stored in reservoirs during the rainy season, and this supply may then be drawn on as needed; or it may be obtained from the underground supply.

238. Diversion of streams constitutes the most obvious means of obtaining water. Immense quantities of water are carried constantly in the rivers that flow to the seven seas of the world, and if this could be utilized in the growing of crops the gain to mankind would be very great indeed.

There are many examples in the United States of diversion of stream flow on a large scale. The Uncompahgre project in Colorado is one of the largest in the history of irrigation

in America. Because of the problems encountered, it is also of intense interest.

Two river valleys in Colorado, the Gunnison and Uncompahgre, lie parallel. The Gunnison River carries a large amount of water and it flows through a narrow precipitous canyon, offering no opportunities for agriculture. The Uncompahgre River carries a very small amount of water, but flows through a broad and fertile valley, promising large opportunities for agricultural development. The project which the United States Government undertook was to bore a tunnel through a range of hills separating the two valleys; and through this tunnel to divert the water from the Gunnison River, using it to irrigate the Uncompahgre Valley.

In the prosecution of this work, problem after problem was encountered that could not have been foreseen. To begin with, the task was one of great magnitude. Not only was the tunnel a stupendous problem in itself, because of its size, it being six and one-half miles long; but in addition, intake, canal, and distributing systems had to be constructed. As the boring of the tunnel progressed, unexpected problems arose. Large quantities of water and of carbon dioxide gas were encountered. At one point extensive layers of gravel and sand were found where solid rock had been expected; and the tunnel had to be lined with a thick wall of concrete. Work was begun in February, 1905, but the tunnel was not completed until January, 1910.

239. Imperial Valley.—The bringing of water to the Imperial Valley in California is one of the best known irrigation projects ever undertaken in the United States. The irrigation of this valley was first attempted by private capital in the year 1900. In the view of the men who undertook the project, their problem was comparatively simple. They diverted the water from the Colorado River by means of a canal which tapped the stream, as the Colorado is a

large river with a fairly continuous flow during the summer season when demands for water are heaviest.

The Imperial Valley is bounded on east and west by mountains and on the southeast by the Colorado River. Since the land slopes in a northwesterly direction from the river to the Salton Sea, it seemed simple to divert a small portion of the stream into canals and carry it over the valley for irrigation purposes. One geological factor, however, the builders failed to take into account. The Colorado River flows along what has been described as the top of a hill. Like the Mississippi, the water level of the stream is higher than the adjacent country, with the resulting danger of overflow in times of flood. In the northern end of the Imperial Valley is the Salton Sea, a body of water between two and three hundred feet below sea-level. In past centuries the Colorado overflowed its banks, thereby cutting a new channel, and flowed into the region of the Salton Sea. When this region became filled with water, the Colorado was again forced to send its streams to the Gulf of California and in the course of time built up with its sediment a bank which cut off the outlet into the Imperial Valley region. This happened not once but many times, the region of the Imperial Valley being successively an extension of the Gulf of California, an inland lake, and a dried up lake-bed; this process being repeated again and again.

In the spring of 1906 the engineers in charge of the irrigation project were repairing the intake which diverted the waters of the Colorado into the Imperial irrigation system. Unfortunately, the usual spring flood came this year several months sooner than was expected, with the result that the workers were forced to abandon the intake while it was still in an uncompleted condition. A considerable portion of the now swollen river immediately sought this new outlet, flowing down through the valley and into the Salton Sea. It was only by most strenuous efforts and after the expenditure

of large sums of money in constructing a temporary rock dam that the flood was finally controlled and the valley saved.

Since that time, ownership of the irrigation system has been gradually taken over by the settlers themselves, until the actual users of the water are also the owners of the system.

240. Diversion of small streams.—This same process of diversion of stream flow is practiced on a small scale, also, in many parts of the country. Concrete pipe is rapidly taking the place of the old open ditch. It is a little more expensive in the beginning, but saving in labor and water soon makes up.

241. Storage reservoirs serve a two-fold purpose. They store up water for use when needed on farm and orchard; and they regulate stream flow, thereby lessening the danger from destructive floods.

The Elephant Butte reservoir in Texas is one of the largest, if not the largest, storage reservoirs in the world. It impounds enough water to cover between two and three million acres to a depth of one foot. Another large project is the Roosevelt dam in Arizona, located on the Salt River near its junction with Tonto Creek, about seventy-eight miles northeast of Phoenix. It impounds 1,284,000 acre-feet of water which is used in irrigating the farming lands of the Salt River Valley in central Arizona.

242. The underground water supply.—As a rule, water is obtained from this source by means of pumps. The power employed depends on the amount of water desired and forms of energy available. Those most frequently utilized are wind, electricity, and the products of petroleum, such as gasoline, kerosene, and similar substances. There is a definite limit to the height to which water can be raised at a profit, depending on cost of installation and operation of pumping plant, increased return secured by irrigation, and value of the final product.

In a few localities water may be obtained in considerable quantities without pumping, since artesian wells may be secured merely by tapping the underground supply. It is a cheap method of obtaining water but is usually unreliable, for when any considerable number of wells is sunk, the flow is likely to dwindle or cease in all of them. Artesian wells are caused by the water being held in the ground under pressure by impervious strata of soil or rock material; and when this is pierced the water is allowed to escape. If the supply is exhausted faster from the wells than it flows into the underground reservoir, the flow will, of course, soon cease.

243. Application of water.—Water is applied to the ground by flooding, basins, furrows, sub-irrigation, or overhead sprinkling. The method depends primarily on the crop and the soil. Vegetables are frequently grown in beds provided with systems of underground tiles through which water is introduced into the soil. The method is practicable only for crops grown on a relatively small scale or for greenhouse irrigation, but it is an efficient means of applying the water and it leaves the surface of the ground loose and pliable.

Sometimes vegetables are grown in beds depressed below the general level of the ground, and are irrigated by flooding. This is on a small scale the basin method of application of water. Sometimes, also, vegetables are grown on narrow flats somewhat higher than the ground level, and are irrigated by lateral seepage from either side.

Irrigation by sprinkling has come into extensive use in recent years. Permanent pipes are used, and large areas are watered by the simple process of opening a valve. The method is very successful. The only question is the original cost of installation.

Orchards are most frequently irrigated by the furrow method. Water is conveyed through a head-ditch along the highest side of the land, and then distributed over the

orchard as shown in Plate V. The method is familiar wherever irrigation is practiced, but there are still many unsolved questions connected with it. For example, the best length of furrow depends on the character of soil; a light soil requires a relatively short furrow, while the reverse is true with a clay or adobe soil. Frequency of irrigation is another unsettled question, the interval varying from a week or ten days to one or even two months. The amount of water to be applied is another serious problem. Much investigation must still be done before these questions will finally be answered to the best interests of the horticulture of America.

244. Water measurement.—Quantity of water may be designated in a variety of ways; it is most frequently given in cubic feet, gallons, acre-inches, acre-feet, cubic feet a second (called second-feet), and miner's inches. Cubic feet and gallons are units commonly employed to designate the amount of water in a storage reservoir. An acre-foot signifies the water on an acre of land if it be a foot deep; since an acre contains 43,560 square feet, an acre-foot is, therefore, equivalent to 43,560 cubic feet. The acre-inch is the most convenient measure of an irrigation. An application of $2\frac{1}{2}$ acre-inches means that the piece of land in question received water equivalent to a rainfall over the entire piece of $2\frac{1}{2}$ inches. To change acre-inches to acre-feet, divide by 12; *vice versa*, to change acre-feet to acre-inches, multiply by 12. One acre-inch equals 3630 cubic feet or 27,150 gallons. This weighs 226,392 pounds, or 113.2 tons. To change acre-inches to cubic feet, multiply the number of acres in question by 3630, and multiply this by number of acre-inches.

245. Miner's inch.—The common measure of stream flow is the miner's inch. This unit varies somewhat in different states; but is commonly accepted to mean the amount of water flowing through an opening 1 inch square, with the

water maintained at a constant level 4 inches above the center of the opening. This is equal to $\frac{1}{50}$ cubic foot a second, or $1\frac{1}{2}$ cubic feet a minute. Since 1 cubic foot contains 7.48 gallons, it follows that 1 miner's inch delivers practically 9 gallons a minute.

246. Weir measurement.—Another very common device for calculating stream flow is known as the weir; but this is limited in its usefulness to comparatively small streams. It is commonly constructed of wood, faced with metal, especially along the crest of the weir. In calculating stream flow, the observer takes the depth of water flowing over the crest of the weir, being careful to secure the reading at a point far enough back to avoid the curved surface which is formed as the water flows over the crest. This reading

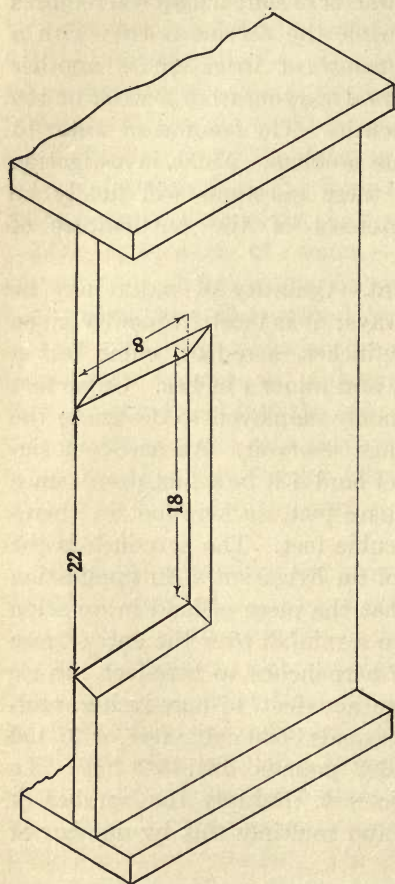


FIG. 98.—Showing construction of Cippoletti weir.

can then be changed to cubic feet a second by using the table on page 156.

The Cippoletti weir was invented by an Italian of that

name (Fig. 98). For each inch of height the sides slope back $\frac{1}{4}$ inch on each side. That is, if the height is 8 inches, and if the width at the bottom 20 inches, then the width at the top will be 20 plus 2 plus 2 equals 24 inches.

Certain precautions are necessary in the construction of this weir. The distance from the crest of the weir to the bottom of the canal or floor of the weir box should be at least three times the depth of water flowing over the weir. The bottom and sides of the weir notch should be beveled on the downstream side to give a narrow edge. Water should approach the weir with a velocity not greater than six inches a second. The water passing over the weir should have a free overfall. An ample distance must be left between the ends of the weir crest and the sides of the ditch or weir box.

247. Water rights.—In almost all agricultural localities water is scarce some of the time; and in the arid parts of the country it is deficient all the time. It is, therefore, valuable to the user, and to protect him and assure him of undisputed right to his fair share, the law-making bodies of the several states have drawn up an elaborate code of water rights. These are in many cases of very great value, exceeding that of the land itself. They depend to some extent on priority of claim. "First come, first served" is the principle on which such rights are based. But there is a growing tendency in America to base the right to water on the use of it. Water, according to this view, is a natural resource the ownership of which is given over to those who will render in return the largest service to society.

Riparian rights, recognized in some states but not in others, are based on a different principle; that is, on the assumption that the farms touching the streams have a prior right to the water. Such rights have given rise to many forms of injustice and are difficult of legal supervision.

The entire matter of water right legislation is growing increasingly complex and important; for as the demand

for the water increases, its value grows in proportion, and adjustments that are fair to all become more and more difficult. The problem applies not only to water diverted from streams or stored in reservoirs, but to the underground water as well.

248. Moderation in irrigation.—Too much water may be as disastrous in irrigation practice as too little. "The best way to irrigate," says one writer, "is with a rake," meaning that the best method to conserve moisture is by frequent and thorough cultivation. But where irrigation water is abundant and cheap, the temptation is always present to use the water rather than the cultivator. This causes poor soil conditions, a rising water-table or the wasting of plant-food through leaching. These serious consequences are in many cases preventable, and serve as stern reminders of the necessity of intelligence in the use of irrigation water.

249. Alkali.—All water that has flowed over or through the ground carries a greater or less quantity of mineral salts in solution. When the water is evaporated by the sun, the mineral salts are left behind, and these give rise to the so-called alkali soils. There is especial danger from this source in irrigated regions, for such localities are receiving fresh supplies of mineral salts with each irrigation. In regions of abundant rainfall, the excess water would wash the ground free from these salts; but in arid or semi-arid climates the matter accumulates year after year and decade after decade, becoming always more concentrated.

There is only one practical way to remove alkali and that is by drainage. Tiles are employed for the purpose in the same way that they are used in other regions for carrying off surplus water; and already the matter of tile drainage is coming up for serious consideration in many of the irrigated parts of the United States.

250. Drainage has for a long time been recognized as of

primary importance. In many sections of the United States it is resorted to not only in the regions of heavy rainfall, but also in localities where rainfall is very slight. By means of drainage, vast areas which otherwise would have been second rate or worthless have been transformed into land of high producing power. The subject is, therefore, as worthy of consideration in some respects as is irrigation with which it is commonly associated.

251. Why drainage is important.—In many sections of the United States, the rainfall is excessively heavy, with the result that the soil is saturated with moisture much of the time. Under these conditions, the decay of vegetation and other chemical processes is not carried to completion and a large number of injurious substances results. Among other things, it is a very common phenomenon in wet soils for acids of one sort or another to be formed. When this happens, the soil is said to be sour. A few plants like the cranberry thrive on this type of land, but most plants require a soil where acid is absent.

The first step in correcting this acid condition is to remove the excess water from the soil. The next step is the application of lime, which reacts chemically with the acid of the soil, neutralizes it, and leaves the land in a non-acid condition.

The soil is not dead and inert as is so commonly supposed, but is teeming with myriads of forms of life. It is also a laboratory in which many and very complex chemical reactions are taking place continually. The best conditions for the life of the soil are: (1) an optimum amount of water, and (2) a plentiful supply of atmospheric oxygen. If the land is too dry, the optimum of water is not present and conditions are poor for bacterial and chemical activity. If, on the other hand, there is too much water in the soil, then the oxygen of the air is excluded and many of the bacterial and chemical changes are shortened on that account. Irrigation supplies water in such a way as to keep as near as possible

the optimum condition as regards moisture. Drainage removes excess water and thus allows the necessary atmospheric oxygen to enter.

252. Drainage of swamp lands.—There are large areas in the United States where the topographical conditions are such that water collects year after year, forming swamps. These areas are commonly very rich in natural soil fertility, for plant-food has accumulated here for centuries and very frequently organic matter has been added in large quantities. The drainage of these lands is an engineering problem which offers in many cases great inducements to the capitalist or the state; financial returns are more or less certain once drainage has been accomplished. On that account, large areas have been reclaimed and are now under cultivation. At the present time there are still many thousands of acres of such lands, especially in the South. When this task is completed, a two-fold good will have been accomplished: a menace to health in the vicinity of these swamps will have been removed, and large areas of land will have been put to productive use.

253. Drainage in irrigated regions.—In many of the irrigated sections of the United States, drainage is coming to be quite as important as in regions of too abundant rainfall. It has been found that irrigation water, applied year after year, very frequently soaks into the soil in such large quantities that the water-table below the surface rises until it becomes a menace to the growing crops. This is especially true if the more deep-rooted plants like fruit-trees are grown. There are two ways of overcoming this difficulty. One is by application of less water. This can frequently be brought about through more intensive conservation of the moisture already in the soil. When, in spite of this, the moisture becomes excessive, the only practical remedy is to drain off the excess through underground tiles.

254. The necessity for irrigation and drainage.—The

time of free lands is past. During the nineteenth century, a continent was to be had for the asking. When anyone in America wanted a farm, all he had to do was to go out to the West and settle on one. Those opportunities are gone, never to return. The land is definitely limited in quantity and in productivity. We must, therefore, make the very best use of it, reclaim it if possible where it lies waste, and put it into the highest possible state of productivity. This is the great problem which the American farmer faces today. In the solution of this, irrigation and drainage play a large part.

255. Horticulture and irrigation go hand in hand. Many of the finest fruit regions of America have been made possible by artificial application of water to land. Deserts have been reclaimed and waste places made to blossom and bear fruit by the magic of the irrigation ditch. But the real problems lie yet ahead. In no type of farming is there such imperative need of intelligence and forethought, for the difficulties are many, and they must be met and solved. The student who is considering these problems now can be assured that he is grappling with questions worthy of a lifetime of thoughtful study.

EXERCISES

EXERCISE I.—Constructing Cippoletti weir, and measuring stream flow.

Materials.—One-inch board six inches wide and about three feet long; saw; pencil; ruler; level; wooden peg one foot long.

Procedure.—For this exercise use any small stream in the neighborhood. If no natural stream is available, produce an artificial one by turning on the garden hydrant. The size of the weir constructed will be determined by the size of the stream available for measurement.

In accordance with description given in the body of the text, construct a Cippoletti weir. Set this board in a furrow in such a way that it will act as a dam, causing the water to flow over the crest of the weir. Drive a peg in the furrow on the upper side of the weir to such a depth in the ground that the top of the peg is level with the crest of the weir. Turn water down the furrow and allow it to flow (but at not too great speed) over the crest of the weir. The peg should be so located that it is covered by the water impounded by this miniature dam. After the

water has been flowing for a short time over the crest of the weir, measure the depth of water over the top of the peg with a ruler and determine from the following table the number of miner's inches of stream flow:

Depth in inches of water flowing over weir	Miner's inches flowing over each inch of weir in length	Depth in inches of water flowing over weir	Miner's inches flowing over each inch of weir in length	Depth in inches of water flowing over weir	Miner's inches flowing over each inch of weir in length	Depth in inches of water flowing over weir	Miner's inches flowing over each inch of weir in length
$\frac{1}{8}$	.01	$3\frac{7}{8}$	2.56	$7\frac{5}{8}$	7.04	$12\frac{3}{4}$	15.27
$\frac{1}{4}$	.04	4	2.69	$7\frac{3}{4}$	7.22	13	15.72
$\frac{3}{8}$	.07	$4\frac{1}{8}$	2.81	$7\frac{1}{8}$	7.40	$13\frac{1}{4}$	16.18
$\frac{1}{2}$	.12	$4\frac{1}{4}$	2.93	8	7.58	$13\frac{1}{2}$	16.64
$\frac{5}{8}$	.17	$4\frac{3}{8}$	3.07	$8\frac{1}{8}$	7.76	$13\frac{3}{4}$	17.10
$\frac{3}{4}$	.22	$4\frac{1}{2}$	3.19	$8\frac{1}{4}$	7.93	14	17.57
$\frac{7}{8}$	.27	$4\frac{5}{8}$	3.33	$8\frac{3}{8}$	8.12	$14\frac{1}{4}$	18.04
1	.33	$4\frac{3}{4}$	3.47	$8\frac{1}{2}$	8.30	$14\frac{1}{2}$	18.52
$1\frac{1}{8}$	.39	$4\frac{7}{8}$	3.61	$8\frac{5}{8}$	8.48	$14\frac{3}{4}$	19.00
$1\frac{1}{4}$	.46	5	3.75	$8\frac{3}{4}$	8.67	15	19.48
$1\frac{3}{8}$	.54	$5\frac{1}{8}$	3.89	$8\frac{7}{8}$	8.86	$15\frac{1}{4}$	19.98
$1\frac{1}{2}$	.62	$5\frac{1}{4}$	4.03	9	9.05	$15\frac{1}{2}$	20.47
$1\frac{5}{8}$	.69	$5\frac{3}{8}$	4.18	$9\frac{1}{8}$	9.23	$15\frac{3}{4}$	20.97
$1\frac{3}{4}$	.77	$5\frac{1}{2}$	4.32	$9\frac{1}{4}$	9.42	16	21.47
$1\frac{7}{8}$	.86	$5\frac{5}{8}$	4.47	$9\frac{3}{8}$	9.62	$16\frac{1}{2}$	22.47
2	.95	$5\frac{3}{4}$	4.62	$9\frac{1}{2}$	9.81	17	23.50
$2\frac{1}{8}$	1.04	$5\frac{7}{8}$	4.77	$9\frac{5}{8}$	10.00	$17\frac{1}{2}$	24.54
$2\frac{1}{4}$	1.13	6	4.92	$9\frac{3}{4}$	10.19	18	25.58
$2\frac{3}{8}$	1.22	$6\frac{1}{8}$	5.08	$9\frac{7}{8}$	10.39	$18\frac{1}{2}$	26.65
$2\frac{1}{2}$	1.32	$6\frac{1}{4}$	5.24	10	10.59	19	27.74
$2\frac{5}{8}$	1.42	$6\frac{3}{8}$	5.39	$10\frac{1}{4}$	10.99	$19\frac{1}{2}$	28.83
$2\frac{3}{4}$	1.52	$6\frac{1}{2}$	5.54	$10\frac{1}{2}$	11.39	20	29.95
$2\frac{7}{8}$	1.62	$6\frac{5}{8}$	5.71	$10\frac{3}{4}$	11.80	$20\frac{1}{2}$	32.07
3	1.74	$6\frac{3}{4}$	5.87	11	12.22	21	33.21
$3\frac{1}{8}$	1.86	$6\frac{7}{8}$	6.04	$11\frac{1}{4}$	12.65	$21\frac{1}{2}$	34.36
$3\frac{1}{4}$	1.97	7	6.20	$11\frac{1}{2}$	13.06	22	35.52
$3\frac{3}{8}$	2.08	$7\frac{1}{8}$	6.37	$11\frac{3}{4}$	13.50	$22\frac{1}{2}$	36.70
$3\frac{1}{2}$	2.19	$7\frac{1}{4}$	6.53	12	13.94	23	37.90
$3\frac{5}{8}$	2.31	$7\frac{3}{8}$	6.70	$12\frac{1}{4}$	14.38	$23\frac{1}{2}$	38.10
$3\frac{3}{4}$	2.43	$7\frac{1}{2}$	6.87	$12\frac{1}{2}$	14.82	24	39.32

EXERCISE II.—Irrigation in the United States.

Materials.—Books on irrigation; encyclopædia and magazine articles and Government bulletins dealing with this topic; also weather maps of the United States.

Procedure.—Using such sources of information regarding irrigation projects as are available in your institution, sketch on Weather Bureau maps or similar outline maps of the United States, the location of the principal irrigation projects of this country.

EXERCISE III.—Irrigation problems.

1. What is an acre-inch?
2. How many square feet are there in an acre?
3. How many cubic feet of water are contained in one acre-inch?
4. What is meant by a "second-foot?"
5. What is the relation between a second-foot and a miner's inch?
6. How many second-feet are delivered by a stream of fifty miner's inches flowing for one hour?

7. What relation is there between this and one acre-inch?
8. Utilizing the answer to the above question, answer the following questions:

a. How many acre-inches will a stream of 50 miner's inches deliver to 10 acres of ground in 24 hours? The volume of a circular reservoir with perpendicular sides is ascertained according to the following formula:

V equals $\pi r^2 H$

π equals 3.1416

r equals radius of circle

H equals Height

b. How many cubic feet in a circular reservoir with a radius of 50 feet and a height of 10 feet?

c. If a river has a flow of 1000 second-feet, how many acres will it irrigate with five acre-inches of water during a period of thirty days?

CHAPTER XII

POLLINATION AND FERTILIZATION

POLLINATION and fertilization are essential to the formation of seed, and the development of seed is necessary, in most cases, to the production of good fruit. A few kinds of seedless fruits have proved satisfactory, of which the seedless grape and certain varieties of the orange are very valuable examples. The banana is also seedless, as is the pineapple. But with most fruits the seed and pulp must develop simultaneously. It is only in comparatively recent times that the commercial importance of the subject of pollination and fertilization has been realized and that a careful study has been made of its relation to fruit production.

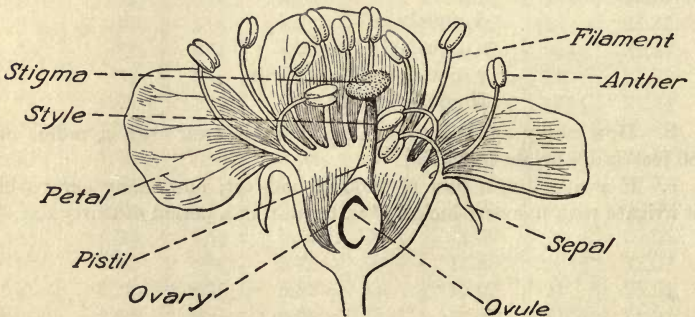


FIG. 99.—Cherry blossom.

256. The flower and its parts.—To understand the nature of pollination and fertilization, one must first be familiar with the structure of the flower. In Fig. 99 is shown a cherry blossom with the various parts labeled. On the outside is a

green-colored member known as the calyx, divided into several leaf-like parts, each of which is called a sepal. The calyx protects the young flower-bud from insects, winds, rain, and possibly in some cases from cold. Inside of the calyx is the colored showy part of the flower known as the corolla, the divisions of which are called petals. The bright colors of the corolla attract bees and other insects. A further examination of the flower reveals a number of slender members, the stamens, or male organs of the plants, each consisting of a thread-like part (the filament) and a knob-like enlargement (the anther). Pollen-grains are produced within the anthers. The pistil or female part of the cherry blossom is a vase-shaped organ in the center of the flower. The somewhat expanded portion of the top, known as the stigma, receives and holds the pollen-grain at the opportune time and secretes substances to cause the grain to germinate. At the bottom of the pistil is a bulge, the ovary or seed case, which, after fertilization has taken place, holds the developing seed.

257. Pollination and fertilization.—Before a seed can be formed, a certain cell contained in the pollen-grain must be brought in contact with a particular cell in the ovary so that the two cells may unite or fuse. When the pollen-grains are mature, the anthers crack open (dehisce) and liberate them. They then fall upon or are carried to the stigma. The alighting or placing of the pollen-grain upon the stigma is known as *pollination*.

Soon after the pollen-grain has alighted upon the receptive stigma, it begins to swell and puts forth a tube. The pollen-tube continues to lengthen, grows down the style, and finally reaches the ovary through a little opening called the micropyle. The nucleus is then discharged from the tip of the pollen-tube, and fuses with the female nucleus in the ovary. This process is called *fertilization* (Fig. 100). After the two cells have fused, a division takes place (Fig. 101).

First two cells are formed, next four, then eight, and this dividing continues until there are many cells, resulting finally in the seed with its embryo plant. Pollination and fertilization, then, are both necessary for the formation of seed.

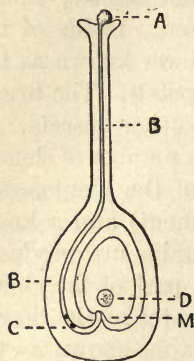


FIG. 100.—Fertilization. The pollen-grain (A) on the stigma has sent a tube (B) down the style and through the tissues of the ovary. The tip of the pollen-tube is entering the micropyle (M). The pollen nucleus (C) is descending the pollen-tube to fuse with the egg nucleus (D).

258. Organs essential for seed production.—Only two organs are necessary for the production of seed, the pistil (Fig. 102) and the stamens. These, therefore, are called the essential organs of the flower. The calyx and corolla, called together the perianth, though frequently of service, are not necessary for seed production, and in flowers of many plants either one or both is wanting. While stamens and pistils are necessary for seed production, both need not be present in the same flower or

even on the same plant. A flower having both essential organs, as the cherry blossom, is said to be perfect. One possessing either stamens or pistils but not both is imperfect. Flowers possessing stamens only are staminate, and those having pistils only are pistillate.¹ When stamens and pistils are borne separately in different flowers and both types of flowers occur on the same individual, the plant is monœcious.² Such a plant, of course, has no perfect flowers. Indian corn, pumpkins, cucumbers,

¹ The strawberry is an example of a plant possessing these various types of flowers. Many varieties of strawberry plants produce perfect flowers. Others have imperfect blossoms, containing pistils with imperfect or very few stamens. Strawberry plants with imperfect flowers containing stamens only are rarely found because staminate flowers do not produce fruit and plants having them are not cultivated.

² "Monœcious" means belonging to one household.

melons, oaks, pecans, filberts, walnuts, and butternuts are monœcious. When a plant bears either staminate or pistillate

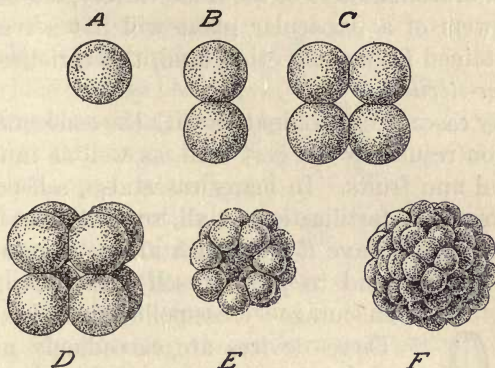


FIG. 101.—Multiplication of cells after fertilization.

flowers, but not both kinds, it is said to be diœcious.¹ Sassafras, hops, poplars, willows, date palms, and most persimmons are diœcious.

259. Relation of pollination and fertilization to the setting of fruit.—While the seed is developing, its surrounding parts, which form the edible portions of most orchard fruits, are also evolving. The formation of the seed is necessary in order that the fruit may set and not drop prematurely, except in the case of the navel orange, and a few other fruits.

A flower is said to be *self-pollinated* when its stigma has received pollen from a flower of the same variety; it is *cross-pollinated* when the pollen comes from a different variety. Flowers which form fruits and seeds when fertilized by pollen from the same variety are said to be *self-fertile* and the process is known as *self-fertilization*. Flowers



FIG. 102—Pistil of the walnut, showing large stigma.

¹ "Diœcious" means belonging to two households.

fertilized by pollen from some other variety are said to be *cross-fertilized*. When a flower will not set seed with pollen from itself or from flowers of the same variety, it is *self-sterile*. When flowers of a particular plant will not set seed with pollen obtained from some other kind, the varieties are said to be *inter-sterile*.

In many cases, cross-pollination with the consequent cross-fertilization results in the best seed, as well as in a heavier set of seed and fruits. In many cases also, self-pollination will not result in fertilization at all, so that it is necessary that many plants have flowers with arrangements of some

kind to prevent self-fertilization, and to encourage cross-pollination by insects. These devices are exceedingly numerous, varied in structure, and interesting, but cannot be described here.

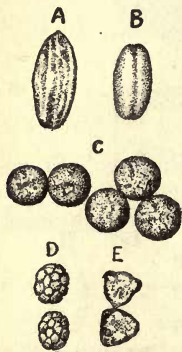


FIG. 103.—Pollen-grains. A, Kieffer pear; B, California almond; C, wild poppy; D, acacia; E, hazelnut.

260. Requisites for fertilization.—In order that fertilization may take place, both the pollen and the pistil must meet certain requirements. The pollen-grains (Figs. 103, 104) must be viable, that is, they must be capable of germinating, of producing a tube, and a cell capable of uniting with the egg-cell of the ovary.

Many factors affect the viability of pollen:

(1) Pollen must be mature. It must have reached a certain age and passed through a definite period of development before it can germinate and fertilize the ovule. This development takes place within the anther, which, as we have seen, cracks open at the proper time and liberates the pollen-grains. On the other hand, pollen-grains which are too old will not germinate, or if they do may not fertilize the ovule. (2) The vigor of the tree affects the viability of the pollen. Healthy trees generally produce better pollen year after year than do sickly, small, stunted ones. (3) The age of trees has

some effect on the viability and abundance of pollen. In some cases very old trees produce pollen less viable than do the younger individuals. (4) Weather conditions affect the development and transportation of pollen. Sunshiny dry weather which enables bees to work during blossoming time is favorable. Rain at the time the blossoms open is unfavorable, because it not only soaks the dry pollen which has



FIG. 104.—Pollen-grains of the Drake almond.

been shed by the anthers to a degree that injures it, but frequently washes it away so that it is lost. Many flowers have ways of protecting the anthers and pollen from rains, such as by drooping so that the rain-drops will be shed, or by curling up the stamens so that the anthers are drawn into shelter. Hot dry winds are unfavorable on account of their dessicating nature. Pollen-grains from most kinds of fruit-trees, however, withstand considerable hot weather and sunshine. Frost, when at all severe, may injure the anthers, but in most cases the pistils are injured before the anthers suffer.

The relation of the pistil to pollination and fertilization is important. (1) The stigma must be receptive. This means that it must be of the proper age and condition to hold the pollen-grain and to furnish the necessary stimulus to cause it to germinate. The stigmas in flowers of common fruit-trees usually remain receptive for several days. Receptive stigmas are neither too dry nor too green. They usually take on a peculiar glistening appearance and produce a sirupy or sticky fluid on the surface which causes the pollen-grains to stick tightly. The stigmatic secretions seem to favor the germination of pollen-grains of certain varieties and to prohibit the germination of those of other sorts, but the chemical action involved is not at present well

understood. (2) The style must be of the proper length so that the tip of the pollen-tube will just reach a point near the micropyle of the ovary at the time the tube is ready to discharge the pollen-cell which will fertilize the ovule. On this account pollen-grains which normally produce tubes shorter than the length of the style cannot successfully fertilize the ovule. In some instances, pollen-grains normally produce pollen-tubes much longer than the style, and the tip of the tube grows past the micropyle before being ready to discharge the cell to fertilize the egg-cell. In either of these cases, fertilization cannot take place. (3) The tissue of the style must be of such structure that the pollen-tube can penetrate it. Sometimes the style possesses a stylar canal, an opening down which the pollen-tube makes its way, but often the tube grows down through the tissues, either forcing its way between the cells, or actually dissolving some of them and absorbing the dissolved material to aid in its own growth. (4) It appears that the cell of the ovary must have a certain attraction or affinity for the pollen-cell, otherwise fusion of the two does not occur. This attraction is probably chemical in nature, but is not well understood. (5) Weather, conditions may be favorable or unfavorable in relation to the pistil. Sunshine is generally favorable, especially by rendering it possible for bees to carry pollen from flower to flower. Rainy weather is unfavorable to mature stigmas, inasmuch as the water washes away some of the stigmatic secretions. Dry hot winds tend to cause drying of the stigmas.

261. **Transportation of pollen** is of great importance. In some of the lower forms of plant life, the little sperm, corresponding to the pollen-cell of higher plants, is motile and can swim through films of moisture to the egg-cell of the female organ, but in higher forms some outside agency must be depended on for bringing the pollen to the stigmas of the pistils. There are three main transporting agencies: water, winds, and insects.

1. Water, as an agent in carrying pollen, is of importance to a number of water plants. The pollen floats on the water to the stigmas. From a horticultural point of view, this method of transportation is of little importance.

2. Plants depending on winds for pollination are said to be anemophilous. A considerable amount of the pollen carried by wind is scattered and wasted. Consequently, anemophilous plants produce enormous quantities of it. The pollen-grains are commonly small with dry surfaces, which prevent their sticking together. In many cases, pollen-grains possess air bladders which facilitate wind transportation. Various modifications of the usual form of pistil are frequently present in cases in which wind is depended on to carry the pollen. An example of this is shown in the many branched spreading style of the hazelnut which is especially adapted to catch and hold pollen-grains floating in the air. Many of the nut-trees, such as the walnut, butternut, and pecan depend on wind pollination.

3. Insects are the most important carriers of pollen. The common fruit-trees depend largely on bees for pollination. Such plants encourage bees to visit them by producing a supply of nectar, which is usually secreted by nectar-glands located well down at the base of the pistil or in the lower parts of the flower, so that the bees, in order to obtain the nectar secreted by the glands, must scramble down into the flowers and get well dusted with pollen in doing so. Flowers depending on insects for pollination, unlike wind-pollinated ones, generally produce pollen-grains of good size, comparatively speaking, and frequently the outside of the grains is somewhat sticky. Such pollen-grains stick to the hairy legs, wings, body, and head of the bee. In going from flower to flower, the bee not only picks up pollen but distributes it, for as it goes in search of nectar it brushes some of the pollen against the stigmas, where numerous grains stick, and pollination is accomplished. Flowers de-

pending on bees for pollination are said to be entomophilous, and attract the bees by their odor and by their large showy petals,¹ while wind-pollinated flowers are commonly small and inconspicuous.

262. Ways to distinguish good from poor pollen.—It is of value to the practical fruit-grower as well as to the scientific worker to be able to distinguish good from poor pollen without actually pollinating blossoms and waiting for the crop to set. Microscopic examination (Fig. 105) is

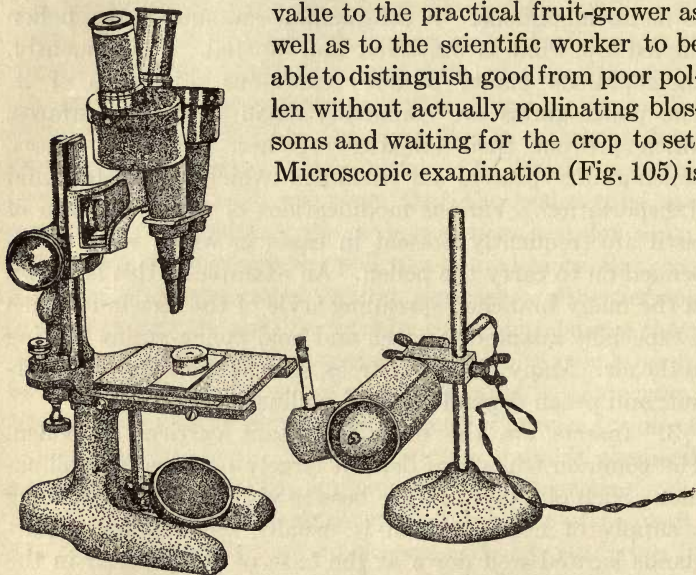


FIG. 105.—Showing Van Teighem cell with pollen-grains mounted for examination under a binocular microscope.

a fairly accurate way of determining whether or not pollen is viable. Artificial germination is a sure method. To deter-

¹ It is interesting to note in this connection that flowers supply bees not only with nectar for honey-making, but with pollen for food as well. If bees are watched for any length of time while they are at work on blossoms, they will be seen gathering pollen and stuffing it in curious pocket-like arrangements of bristles on the outside parts of the hind legs. The bee-bread found in the brood combs is merely this pollen, which together with nectar and honey constitute their food. These industrious insects distribute pollen so economically that much less pollen is necessary to insure pollination and fertilization in entomophilous plants than has to be produced by anemophilous plants for the same purpose.

mine which are the good pollen-grains in a sample by use of the microscope, it is necessary first of all to know what is the normal size and shape of the grains. The normal appearance of the grains differs in various species and even in varieties. An examination of the pollen-grains shown in the photomicrograph in Fig. 104 will make this plain. It will be noticed that some of the grains are large in size, others are small, and some are medium and regular in outline. Whenever pollen-grains depart from their usual size and shape, it is reasonably certain that they lack viability and will not germinate. Grains smaller than normal or very much larger seldom germinate. Such grains can be seen among the normal ones in the illustration.

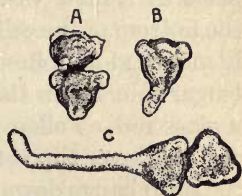


FIG. 106.—Germination of Black Heart sweet cherry pollen. A, grains swelling; B, tube starting; C, later stage of tube growth.

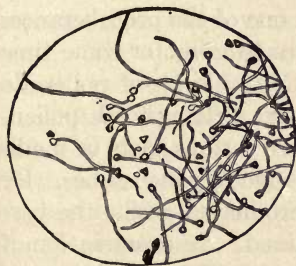


FIG. 107.—Photomicrograph of California almond pollen-grains germinating. These grains were mounted eight hours before photographing. Notice the length of the tubes and the high percentage of germination.

A microscopic examination of pollen-grains, then, will reveal those that are "off-type" and will not germinate.

Although it is fairly certain that the grains apparently normal will germinate, this is not always the case. On this account, it is necessary to have accurate methods of testing the viability of pollen-grains. This is done by placing them in artificial media. Pollen-grains from most varieties of fruit-trees germinate well in a

solution of sugar and water in which the sugar constitutes 12 per cent of the mixture. That the pollen may have as favorable conditions for germinating as possible, it is mounted in the culture in a closed glass chamber known as a Van Teighem cell, one of which is shown

in Fig. 105. This cell consists of a ground glass ring fastened on a microscopic glass slide with paraffine or vaseline.¹ A glass cover-slip is placed on the top of the ring and held in place by a little vaseline. A few drops of water are put in the bottom of the cell to keep the chamber moist. The pollen is mounted as follows: A drop of the germination medium (sugar solution in this case) is applied to the cover-slip with a glass rod. Pollen is dusted upon the surface of the drop, and the cover-slip is then placed on the vaselined ring so that the drop hangs downward, and is within the moist chamber. The pollen can then be examined with a microscope at any time. (See Fig. 105).

After the grains are mounted, they begin to absorb moisture through their coats and swell. Soon the viable grains put forth tubes, which continue to grow until they attain considerable length. The grains of pollen, on absorbing moisture, first change their shape from elliptical to round. Next three protuberances appear. From one of the protuberances the pollen-tube starts, and continues to grow for some time as is shown in Figs. 106 and 107. Many kinds of pollen do not assume this triangular shape before putting forth pollen-tubes. Frequently pollen-grains have certain spots or modified places in their coats for the emission of pollen-tubes. By counting the germinated and non-germinated grains the percentage of germination can be obtained. An examination of the photomicrographs will show that a high percentage of germination may be expected from almond pollen (Fig. 107). The percentage of germination of pollen of most apple varieties is also high. On the other hand, Japanese plum pollen and many varieties of sweet cherry pollen give comparatively low tests. The hazelnut pollen, Fig. 103, shows a very

¹ While glass rings, which may be obtained from dealers in optical supplies, are best for this purpose, fibre rings or rings of sealing wax may be employed instead. If sealing wax is used, it is softened in a flame and applied to the slide in the form of a circle, after which the top is leveled off with a sharp knife. Hollow ground-glass slides may also be used.

low germination test. In fact, pollen from trees and shrubs which depend on wind for distribution is seldom high in germination percentage.

In case of pollen from common fruit-trees, the germination test in sugar solutions indicates the viability of the pollen, for grains which will not germinate in the sugar solutions will not germinate and fertilize the ovules when applied to the stigmas. In fact, germination media are known with which to test the viability of any sort of pollen, although no one medium has been found which works equally well with all varieties.

263. Viability of pollen affected by various factors.—In addition to the factors already mentioned, climate, moisture supply, physiological conditions of the tree, and earliness of bloom affect the viability and production of pollen. However, some species and varieties of trees produce better pollen than others. This characteristic seems to be inherited and remains true (but is varied by other conditions) from year to year. The Combination plum is an example of a variety which produces pollen of poor viability and also in very scant amounts. Its pollen is not sufficient in quantity and viability to fertilize other trees successfully. In general, it may be said that some species of trees naturally produce pollen of higher viability than others, and may also yield pollen in larger quantities. The apple produces pollen in abundance and of high viability. Varieties of trees differ in the amount of pollen borne. Individual trees also differ in this regard. Many hybrids, that is, plants resulting from the crossing of species, produce only a scant quantity of pollen which is frequently not viable.

264. Inter-planting for pollination.—Inasmuch as pollination bears directly on fruit production, every orchardist is vitally interested in planting the correct mixture of varieties. Many pollination problems are still unsolved. Much experimenting is being done to determine which varieties are

self-fertile, which self-sterile, and which inter-fertile, and to discover what crosses produce fruit in greatest abundance. This is performed by artificially pollinating the blossoms.

265. Artificial pollination.—In all artificial pollination, the principles taught by nature are utilized. The important points to bear in mind are to secure viable pollen, to insure the application to the stigmas of the kind of pollen desired, to exclude from the stigmas all other pollen, and to keep accurate records of the results.

The operations in artificial pollination are the following:

1. Procuring, treating, and keeping the pollen.
2. Preparing the flower for receiving the pollen, and taking steps to prevent pollination by other means than those intended.
3. Applying the pollen at the proper time.
4. Keeping the records.

266. Procuring the pollen.—It is not only necessary to secure the pollen, but it is convenient and sometimes imperative that it be kept for a short time. There are a number of good methods of collecting pollen. In the case of plants which are ordinarily wind-pollinated, as in the chestnut and walnut, all that is necessary is to procure branches on which the anthers have begun to dehisce and place them on newspapers in a dry room, or still better in sunshine under a glass cover such as will keep out wind and insects. In a few hours, or a day or two, an abundance of pollen may be shaken out on the newspapers. If the pistillate flowers of the walnut are to be pollinated at once, it is only necessary to shake a branch having ripe pollen over a branch of the pistillate flowers. To prevent pollination by the wind, it is necessary to place paper bags over the portions of the branches to be pollinated sometime before the stigmas are receptive. The bags are removed for the pollinating and are replaced again.

In the case of ordinary fruit-trees, which depend on insects for pollination, different methods are necessary. It is im-



Plate V.—Upper: Irrigating a nursery by furrow system.
Lower: Irrigating orchard by basin system.

portant to remember that pollen should not be collected from flowers which have already opened, because bees working on the blossoms will have brought pollen from other flowers and it will be mixed; therefore, in selecting blossoms from which pollen is to be obtained, it is necessary to choose flowers not yet opened. It is best to select buds which are full-grown and almost ready to open, but whose petals as yet are closed so that bees have not entered. These buds can be picked and placed in paper bags.

One method of obtaining pollen from the blossoms is to pull off the corolla and place the flowers on newspapers in the sunlight until the anthers dehisce and shed the pollen. A much neater way is to scrape or cut the anthers out of the bud; in this way they can be obtained nearly free from other material. The anthers are placed in a watch glass and dried in the sun until the pollen is shed. It is best to put the watch glass on clean sand in a shallow box, which should be covered with a pane of glass to prevent the entrance of insects and dirt. When a large number of samples of pollen are to be dried, especially constructed glass cases are generally used. The anthers will dry in bright sunlight in a few hours, or at most in two days.

267. Storing the pollen.—Pollen prepared as indicated may be used for pollinating purposes at once or may be stored and kept for several days or even for a few weeks. Many kinds of pollen may be kept from two to six weeks under favorable conditions, but pollen usually deteriorates after a few days, and the longer it is kept the lower its viability becomes. There are, however, exceptions to this rule; for example, pollen from the date palm has been kept viable for years.

In storing pollen it is necessary that it be kept dry in order to prevent molding. A convenient way is to brush the pollen and anthers from the watch glass into a glass vial. Ordinarily it is well to cork the vials with cotton, although in some

climates it is considered best to use cork for the purpose. Pollen is sometimes stored and shipped in capsules such as are employed for holding quinine and other drugs. It can also be kept in paper bags tied securely.

268. Emasculating the flowers.—The flowers to receive the pollen are prepared a short time before the stigmas are receptive. In order to prevent self-pollination, perfect flowers, like those possessed by most fruit-trees, must have the anthers removed before they are ripe. This process is known as *emasculation*. The flowers must be emasculated before the petals open in order to prevent the carrying of pollen to the stigmas by insects, and as soon as emasculated should be covered with paper bags. Flowers may be emasculated a few days before they would naturally open. In preparing a twig for emasculation, all immature buds and those too far advanced should be removed.

In emasculating flower-buds of the common stone-fruits (as plum, cherry), enough of the perianth is removed to take away all the stamens. A study of the flower will show just how much of the calyx it is necessary to remove in each variety. There are several ways of emasculating flowers of this type. One way is to cut through the calyx clear around the flower-bud with small scissors, leaving the pistil intact. Another method is to make the cut with a sharp scalpel. A better and faster way of emasculating flower-buds of this type was originated by E. J. Kraus at the Oregon Experiment Station. This consists in removing the proper portion of the perianth with the finger-nails (See Figs. 108–110). The thumb and second finger are used to cut through the side of the bud as illustrated in Fig. 109. The beginner will make two cuts with the nails, one on either side of the bud, and at the second will lift the loosened perianth over the top of the pistil. As one becomes more expert, he will make but one cut on the side of the bud, tearing around the bud and removing the perianth at the same time. By using this method it is possible to

emasculate a flower with one motion. As many as 1200 cherry blossoms have been emasculated, bagged, and labeled by one man in a single hour by this method, although from 500 to 800 blossoms an hour are nearer the average for each man.

With pome-fruits, such as the apple, pear, and quince, the calyx-tube or hollow torus develops into a portion of the fruit. When blossoms of the pear and apple are emasculated by the method just explained, the fruit formed will be somewhat deformed. In order to prevent fruit-deforming, it is the custom in emasculating flowers



FIG. 108.—Position of the fingers for emasculating.

of the pome-fruits to leave the calyx, merely removing the petals and anthers. With the thumb and second finger the

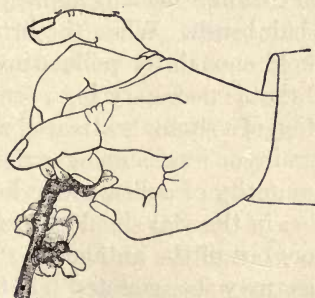


FIG. 109.—Cutting through the calyx with the finger-nails.

corolla is grasped, a little to one side near the top, and pulled off. Care must be taken not to grasp the pistil, otherwise its top will be torn off when the petals are removed. The flowers minus the corolla will be seen to have the stamens attached to the rim of the calyx-cup. The stamens can be scraped off by

running the points of curved forceps around inside the rim of the cup. If any of the anthers fall into the calyx-cup, they can be blown out with the breath. This is a fairly rapid method, it being possible to emasculate, bag, and label about 200 blossoms an hour.

269. Bagging the blossoms.—Although bees do not visit

emasculated flowers to the extent that they do others, it is advisable to tie a bag over the ends of twigs, covering the emasculated blossoms. The bags, in addition to keeping insects out, also serve as some protection to the pistils from

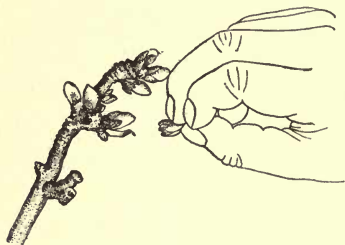


FIG. 110.—The perianth removed.

drying winds. Each twig is labeled with the number of blossoms emasculated, the date, and such other information as may be desired. Fairly durable tags should be used.

270. Applying the pollen.—After the flowers are bagged, some of them are

examined from time to time, and when the stigmas are bright, shiny, and sticky, they are ready to receive the pollen. The pollen, which has already been placed in labeled glass vials corked with cotton, is usually applied to the stigma with a small camel's hair brush. When the brush is dipped in the pollen, it will hold enough for pollinating a large number of stigmas, and all that is necessary is to touch each stigma with it. Examination of a stigma so treated will show a large number of pollen-grains on its glistening surface. It will be noticed that a small quantity of pollen goes a long way in pollination. If the pollen in the vial should become scanty, a few shakes will jar more out of the anthers.

271. Labeling.—The stigmas may be counted as the pollen is applied and the number, together with other information, written on a tag attached to the twig. The record of each tag may be kept in a notebook or on cards. After the pollen is applied, the bags are replaced, and later, after the fruit is set, they are removed, and such observations as are necessary are made and recorded. The tags may be left as long as desired, and observations and records made from time to time.

272. Checks.—It is necessary in all work of this nature to

be able to compare the set of fruit obtained as the result of cross-pollination with that secured under natural conditions. Blossoms are counted on twigs similar to those cross-pollinated and the twigs are tagged. The effect of cross-pollination can then be estimated correctly by comparing the set of fruit on the twigs artificially pollinated with that on twigs pollinated under natural conditions.

273. Choosing varieties for pollination purposes.—By extensive experimenting, the kinds of pollen can be found which give the best set of fruit for any particular variety. In order that an abundance of fruit may set, the grower must in many cases inter-plant with trees of the proper variety for supplying suitable pollen. It is important to know that some varieties are inter-sterile, that is, will not set fruit when cross-pollinated. For example, the Bing and Napoleon (Royal Ann) sweet cherries are inter-sterile. The Bing will not set fruit when pollinated with the Napoleon pollen, and neither will the Napoleon set fruit when pollinated with Bing pollen. In like manner, Nonpareil and IXL almond varieties are inter-sterile.¹ On the other hand, some varieties are inter-fertile, that is, their pollen will fertilize each other. The Napoleon and Black Republican varieties of sweet cherries are examples.

Some fruit-trees are self-fertile, or will set fruit well even when self-pollinated. Most peach trees are self-fertile. In setting out an orchard, in addition to selecting good commercial varieties, the grower must select kinds which are either self- or inter-fertile. In the past, many growers have planted large blocks of a single desirable commercial variety of fruit, only to learn after a number of years that the sort would not produce well because it was self-sterile. Indeed, it is not sufficient to know that a variety is generally self-sterile or self-fertile, but the grower should know the facts with reference to his own section of the country. For ex-

¹ Bull. 306, Calif. Exp. Sta.

ample, the Bartlett pear is self-sterile in the East, but is self-fertile in the Pacific Coast states, although cross-pollination may increase the crop even in the Pacific states.

274. Requisites of good pollinizer.—In choosing trees for pollinating any variety, several requisites of good pollinizers should be carefully considered.

1. Varieties must not only be able to pollinate each other, but must produce pollen at the time it is needed by the other trees; that is, they must bloom at approximately the same time. If one variety blooms early and the other late, the pistils of the early-blooming sort will be past the receptive stage when pollen of the late-blooming kind is ready, and the pistils of the late-blooming variety will not be receptive until sometime after the pollen from the early-blooming tree has been shed. For example, it would be of no use to inter-plant Chapman and Napoleon sweet cherries for inter-pollination, because the Napoleon does not blossom until the Chapman has finished its blooming period.

2. Any variety intended for pollinizing another kind must produce viable pollen in abundance. The Combination Japanese plum has already been mentioned as being unsuitable for pollination purposes, as it produces pollen very sparingly.

3. Late-blooming varieties escape frost more often than early-blooming ones. This is not only the case with fruit that has already set, but is true also of the flowers just after they have been pollinated, and before the pollen-tube has reached the ovary. Some species of early bloomers will stand frost better than others. Japanese plums, for example, will stand more frost than apricots, even in case of those varieties blooming at the same time.

4. Varieties which are good from a commercial standpoint should be chosen for inter-pollination. For example, if it is desired to plant varieties of pears for pollinating the Bartlett, a kind should be chosen which will pollinate the

Bartlett and also produce a good crop itself, as a result of fertilization either from Bartlett pollen or from its own pollen.

5. In some cases it may be desired to plant mostly one variety and just enough of the pollinizer to insure production of the desirable fruit. As an illustration, suppose that one wishes to grow Warfield strawberries for market. As the Warfield bears pistillate flowers only, it will be necessary to plant rows of some variety having stamens to fertilize it. Suppose that the Lovett is chosen for this purpose. As the Lovett bears perfect flowers and is self-fertile, it will bear fruit without being cross-pollinated, and will at the same time furnish pollen for the Warfield. Although the Lovett is a good berry, it does not stand shipping so well as the Warfield and the grower will prefer the Warfield. On account of desiring as large a proportion of Warfield berries as possible, instead of planting every other row of the Warfield patch with the Lovett, the grower will plant much less, probably every third or fourth row with the Lovett, an arrangement which would furnish an ample number of plants to pollinate the Warfield. The grower will then have a good combination for the purpose intended.

If trees do not bear well and the reason is not apparent, the orchardist should study them as to quantity and viability of pollen, self-sterility (or inter-sterility and relative blooming dates if he has more than one variety) and, in general, as to the availability of suitable pollen for fertilizing the blossoms. Owing to variations in the behavior of varieties in different sections of the country, the grower should obtain information from the nearest experiment station as to the desirable combinations to plant, insofar as such information can be given.

EXERCISES

EXERCISE I.—Study of flower structure.

Materials.—Blossoms of fruit-trees; sharp knife or scalpel; magnifying glass.

Procedure.—Study various flowers for the purpose of becoming familiar with their structure. Make diagrams showing the different parts. Label all parts. Compare flowers of species of fruit-trees, note any differences in their structure.

EXERCISE II.—Study of pollen-grains.

Materials.—Flower-buds from various fruit-trees; watch glasses or petri dishes in which to dry anthers; microscope; glass slides and cover-slips.

Procedure.—Collect some flower-buds, remove the anthers and dry according to methods described in this chapter. Examine the grains of various pollens by use of the microscope. Sketch typical grains, making drawings large enough to show their shape. Store some pollen for future use according to methods given in this chapter.

EXERCISE III.—Germination of pollen-grains and the study of their tubes.

Materials.—Van Teighem cells, or materials for making the same (see paragraph 262); sugar solutions; pollen-grains.

Procedure.—Mount some pollen-grains in hanging-drop cultures as described in the text. Examine them from time to time in order to observe the pollen-tubes of different lengths. Make drawings showing some of the germinated grains with their pollen-tubes. Notice the comparative size of grains, diameter and lengths of the tubes, and rates of growth of the tubes in different varieties of pollen. The following are a few suggestive species of orchard trees and bush-fruits from which pollen may be obtained at the proper time: almond, apple, apricot, European plum, Japanese plum, peach, pear, walnut, grape, raspberry, blackberry, date palm.

EXERCISE IV.—Practice in emasculation of flowers.

Materials.—Fruit-trees in bloom.

Procedure.—Emasculate some blossoms when they have reached the proper stage according to methods described in this chapter. Apply some pollen to the stigmas. Notice how tightly the pollen sticks.

EXERCISE V.—Exercise to show the effects of self-pollination versus cross-pollination on the setting of fruit.

Materials.—Fruit-trees in bloom; viable pollen of different varieties of the species emasculated; tags, paper-bags, and string.

Procedure.—Select a variety, carefully emasculate, and bag the blossoms on a number of branches. When the stigmas are receptive,

pollinate a number of flowers with pollen from the same variety. In the same way, pollinate stigmas on some branches with pollen obtained from other varieties. Rebag and label the twigs. Make records and notes carefully. Later in the season obtain the percentages of fruit set in the different cases. From the results determine what pollen produced the best set of fruit and what varieties would appear to do best when inter-planted.

EXERCISE VI.—Blooming periods.

Materials.—Various kinds of orchard trees in spring time.

Procedure.—Keep blossoming records in a tabulated form for different varieties of fruits in your locality. Record the following facts for each variety:

- a. Date when buds show first signs of swelling.
- b. Date when color of petals shows distinctly in bud.
- c. Date when flower-buds are right for emasculating (just before petals open).
- d. Date when flowers are wide open, that is, when tree is in full bloom.
- e. Date when most of the petals fall.

By some kind of a diagram indicate the blooming periods of the different varieties so that it may be seen at a glance just how far the varieties overlap so as to be useful for inter-planting for purposes of pollination, assuming that the varieties are inter-fertile.

EXERCISE VII.—Project exercise. If the student has access to a tree of relatively poor bearing qualities, he may make it his study to ascertain: (a) whether or not the tree produces viable pollen; (b) how the viability of its pollen compares with that of good bearers of the same variety; (c) whether or not the tree is self-sterile; (d) whether there is any other variety suitable and near enough to pollinate it; (e) whether or not pollination by any other variety increases its fruit-bearing capacity.

If there is some obvious reason why the tree is a poor bearer, such as poor location, presence of insects or blight, or lack of care, such an exercise would be wasted. Otherwise its results, if carefully obtained, may prove of great interest and value.

CHAPTER XIII

DECIDUOUS FRUITS

TREES that shed all their leaves at approximately the same time are deciduous, while those that retain their foliage the year round and shed their leaves gradually are said to be evergreen.

Many of the deciduous fruit-trees belong to that botanical group known as the Rose family. The Rosaceæ is divided into five or six sub-families or tribes, each of which contains some of the best known fruits and flowers. The Pome tribe includes the apple, pear, quince, and hawthorn. The Bramble tribe contains the blackberry, raspberry, and dewberry. The Drupe tribe is represented by the peach, plum, nectarine, cherry, and apricot. The strawberry belongs to another group known as the Potentilla tribe. The Rose tribe includes the familiar ornamental plants of the same name.

275. The apple.—The history of the apple is obscure. It probably originated in southwestern Asia, but apples are found wild in many parts of the world. There are several wild species in Europe and Asia. According to Bailey, at least five types are native to the United States: the Oregon crab-apple, from Alaska to northern California; two species in the Mississippi Valley, the Garland crab in the North (which may represent more than one species) and the narrow-leaved crab in the South; the Prairie States crab, wild in Minnesota, Wisconsin, Illinois, Iowa, Missouri, and Kansas; and the Soulard crab, which is sometimes considered a cultivated variety, but which Bailey lists as occurring in a wild state from Minnesota to Texas.

Pliny mentions the apple in his writings. A score of varieties were known at that time, but they were, of course, inferior to the modern apple. There is abundant evidence that the fruit was brought to Great Britain from the mainland at the time of the Roman conquest, and in 1688 Ray enumerated seventy-eight varieties in cultivation.¹

The geographical distribution of the apple is greater than that of any other fruit, but the United States and Canada lead the world in its production. In the United States the eight leading apple-producing states, arranged according to acreage are: New York, Washington, Virginia, Pennsylvania, Ohio, Michigan, Missouri, Illinois, Arkansas, and Oregon. The warm Gulf section and a portion of the western prairies do not yield apples on a commercial scale. In Canada, the region beginning with Nova Scotia and extending westward along the St. Lawrence River and the Great Lakes has long been famous for its apples. The following provinces of Canada grow apples commercially: Ontario, Nova Scotia, Quebec, British Columbia, New Brunswick, Prince Edward Island, and Manitoba. Alberta and Saskatchewan also produce some apples.

Apples grow on almost any type of soil, but a deep, fertile, well-drained soil is best. The apple does better on rather heavy loam than it does on sand. The tree will tolerate a considerable amount of gravel, if the soil itself is of good fertility.

In his *Standard Cyclopedia of Horticulture*, Bailey has the following to say concerning varieties: "Each great geographical area has varieties that are particularly adapted to it. In the northern Mississippi Valley, there are few of the eastern-states apples that thrive. Varieties have been introduced from Russia with the expectation that they will be adapted to the region; but more is to be expected of their progeny than of themselves. Varieties of local origin, coming

¹ *Encyclopædia Britannica*.

from various stem types, are now providing that region with satisfactory apples. In the selection of varieties, one should be guided by this adaptation to the region, and by the purpose for which the fruit is designed to be grown. Consult the recommended lists of the state horticultural societies; ask persons who have had experience in the given region; write to the experiment station; enquire at the markets."

The most common disease of the apple is the apple-scab, which is controlled by spraying with bordeaux mixture. The bulletins of the several states should be consulted as to time and method of applying the spray for most efficient results. Lime-sulfur spray is another remedy much used at the present time for the disease.

Of all the insects the apple-grower must combat, the codlin-moth is undoubtedly the worst. The method of control is discussed in Chapter XVI. It should be noted that one spraying is not sufficient, as there are several broods each year; therefore, the process must be repeated at definite intervals, according to the experience of each locality in dealing with the insect. The apple aphid is controlled by nicotine sulfate sprays. The eggs may be destroyed in the winter by the application of kerosene emulsion. Nicotine sulfate is used as a spray for woolly aphid also. Another method of dealing with the woolly aphid on the roots is to scrape off a few inches of top soil and apply kerosene emulsion or tobacco mixtures, allowing it to soak through the soil to the roots. Northern Spy apple stock is most resistant to woolly aphid.

The apple is propagated by grafting and sometimes by budding.

276. The pear.—It is probable that at one time the pear grew wild over southwestern Europe from the Caspian Sea to the Atlantic Ocean. When it came under cultivation, or how, it is impossible to say. The fruit has been domesticated for a long time, for it was well known to the early Greek writers, and there are records of it among the Romans. Over

sixty varieties of pears were listed for sale in the catalogues of London nurserymen early in the seventeenth century. Pear culture was developed to a remarkable extent in France. According to Peter Henderson, a single nursery in France carried a stock of 3600 varieties.

As the pear seems to be somewhat less troubled by its chief enemy, the blight, in regions near large bodies of water than in the dry interior parts of the country, very successful pear sections are those south of the Great Lakes region and east to the Atlantic, and in the Pacific states. California, New York, Michigan, Oregon, and New Jersey have about half the pear acreage in the United States. Eastern Maryland, Delaware, the region along the southern part of Lake Michigan, the Yakima Valley of Washington, and the Rogue River Valley of Oregon are well known pear-producing sections. Pears are not grown to nearly as great an extent in Canada as are apples. They are raised for the most part in the Ontario region west of Lake Ontario, in Nova Scotia, in British Columbia, and to a slight extent on Prince Edward Island.

The pear thrives on heavy soils and will withstand more water than other fruit-trees. Pears will not tolerate a light sandy soil. Care must be exercised in fertilizing the soil, in irrigating, and in cultivating the trees. The organism causing the blight usually enters through the flowers, but it may also gain access through the soft moist tissues of the rapidly growing tips. Any type of fertilization or cultural methods causing a rapid and "sappy" growth should be avoided, especially in seasons when the blight is prevalent.

With the exception of a few varieties, pears are picked green and allowed to ripen in storage, as the flavor is better than if they are allowed to ripen on the tree.

Some varieties of pears in certain localities are self-sterile and require the planting of other kinds with them for pollination purposes.

277. The quince (Plate VI) tree is shallow-rooted and can live on low wet land, although it thrives much better on well-drained deep soils. The fruit is used for making jams, preserves, and jellies. It is much prized in preserves when mixed with other fruits, owing to the distinctive flavor which it imparts. The quince tree is hardy, grows with little care, and produces well.

278. The peach.—It now seems certain that the peach came originally from China. From China it apparently was carried to India and Persia where it came into extensive use; and from here it went to Greece and Italy. After its introduction into Greece about 2000 years ago, reference to it from time to time makes it possible to trace its progress from Italy into France and from France to Belgium, Holland, Spain, and England. Following the discovery of America, the fruit was introduced into Mexico and South America and it is from the varieties that developed there that the group of so-called Indian peaches has arisen.

In the United States, the peach takes high rank commercially, being second to the apple alone among orchard fruits. The regions of the most intense winter cold are unsuitable for peach culture. According to the United States Census reports, over 75 per cent of the peaches produced in the United States are grown south of the Ohio and Missouri rivers and in California. North of the Ohio and Missouri rivers the climate is too severe for their production. The climate, however, is milder along the shores of the Great Lakes and peaches are grown successfully to the south and east of them. In Canada peaches are produced commercially in the Niagara Peninsula and in other parts of Ontario lying along the northern shore of Lake Erie, in western Nova Scotia, and in the lower Okanagan Valley in British Columbia.

The peach, when grown on its own roots, is adapted to a light sandy soil, and does not thrive on heavy clay land. In order to adapt it to heavy soils, it is sometimes grafted on Myrobalan or other plum roots.

Yellows and rosette are serious diseases of the peach for which no remedy is known. Curl-leaf is a fungus controllable by the application of bordeaux mixture or lime-sulfur solution very early in the spring ten to fifteen days before the bursting of the buds.

The three most common insect enemies are the peach-tree borer, the San Jose scale, and the curculio. The first is the most difficult to eradicate. The scale is controlled by spraying, and the curculio by clean cultivation, collecting and destroying the insects, and by spraying. (See Chapter XVI.)

Choice of varieties of peaches depends primarily on market and climate; quality of fruit and resistance of the tree to disease are also factors of importance. In most localities growers select from three to five varieties that are suited to local needs, and whose time of ripening is such that the work of picking is distributed through as long a period as possible. This enables the grower to handle the picking problem with a minimum loss of fruit. Most peach varieties are self-fertile.

The peach is propagated almost entirely by budding.

279. The nectarine is really a smooth-skinned peach. Many varieties have long been grown in Asia. Nectarines have been known to arise from peach trees as bud-sports. It is a fine fruit but is not grown commercially to the extent it deserves. Cultural methods are the same as for the peach.

280. The apricot is probably a native of China or Japan. The Persians named this fruit the "Seed of the sun." The apricot was introduced into England in the early part of the sixteenth century. It is a popular garden fruit in some special locations in eastern United States, and even in the milder parts of the Canadian lake region. Owing to its early blossoming habit, spring frosts limit its production to specially favored localities. California produces practically the entire commercial apricot crop of North America.

The fruit resembles a small peach somewhat and has a pit similar in shape to that of the wild plum. The apricot is

excellent when ripe, and has a peculiar flavor of its own. It makes a fine dried product which is free from the leathery skin and heavy pubescence characteristic of the dried peach. The properly dried apricot maintains its distinctive flavor.

The tree, with its reddish-brown bark and heavy foliage of deep green heart-shaped leaves, is one of the most beautiful in the orchard. It is a strong vigorous grower. When budded on peach root, the apricot thrives on light deep loams. For the heavier loams it should be budded on apricot stock. Attempts have been made with various degrees of success to grow the apricot on heavy soils by budding it on Myrobalan or other plum stock.

Gum disease, brown-rot, and shot-hole fungus are common diseases of the apricot.

281. Plums and prunes.—The plum is spoken of by Pliny in such a way as to indicate that, at the time he wrote, it was a comparatively new fruit. It had probably been brought to Greece and Rome a short time before by some of the raiding hordes from the region of the Caucasus and the Caspian; for there is evidence to support the theory that it first became domesticated somewhere in this region. In America, the plum had begun to assume some importance as a cultivated fruit by the beginning of the nineteenth century. Three types of plums, the European, the Japanese, and the native, are grown in North America.

The Japanese plums are native of China. This species was introduced into America from Japan about 1870, and began to attract attention a few years later. By 1880 it was widely propagated. While the tree is adapted to a wide range of conditions, its early blooming habit renders the blossoms liable to frost-injury. On this account it cannot succeed in all sections where the European plum thrives, but owing to its large attractive fruit, its resistance to plant disease, and its early-bearing habit, it is grown extensively in North America.

In addition to the European and Japanese plums, North America has many native species.¹

Plums are distributed widely over the United States. According to the last census, over one-third of the acreage in plums is in California, the greatest producing section in the world being the Santa Clara Valley which yields about one-fourth of the plums and prunes grown in the United States. Oregon produces large quantities of plums and prunes and Washington a smaller amount.

Canada grows plums over a wide area. W. T. Macoun says: "The plum has not been as profitable to grow in Canada as some other fruits, but with a careful selection of varieties and good care it will be found to give fairly good returns. In those parts of Canada where European plums do not succeed, the improved native and American varieties have been found very profitable. Some of these ripen before the European plums come on the market and they sell at high prices."²

European plums succeed well in Prince Edward Island, Nova Scotia, the south shore of the St. Lawrence River, in Quebec, British Columbia, and Ontario. Japanese varieties are grown in the south coastal region of Nova Scotia, western Ontario, and the milder parts of British Columbia.

It must be kept in mind that when the word "plum" has been used, the "prune" is understood as being included, the prune being a plum that contains sufficient sugar to enable it to be dried without removal of the pit. The two fruits are alike in every other respect. An analysis of the prune from the standpoint of food value shows that it is in a class quite by itself. The dried article contains 2.1 per cent protein and 73.37 carbohydrate; and there are records of prunes, the dried edible portion of which analyzed 50 per cent sugar. It is, therefore, high in food value, yielding nutriment in an easily digested form at a nominal cost.

¹ Bailey, *Evolution of Our Native Fruits*.

² Bull. 43, Dominion of Canada Dept. Agric. Exp. Farms, 1918.

Prunes are usually picked from the ground rather than from the trees; for it has been found that they contain a higher proportion of solids if allowed to remain on the tree as long as possible. The drying process is then completed in one of three ways: In Europe, the fruit is half baked in ovens and drying is then finished in the open air. In California this is usually done out-of-doors, in the sun. In the Pacific Northwest, where the air is more humid, special buildings erected for the purpose, called evaporators, are utilized. Each method has some points in its favor. The European system is said to impart to the fruit an especially desirable flavor, but the product is unsightly, and therefore lacks the marketing qualities of the American fruit. The sunshine method of California is cheap, but cannot be as carefully regulated during each stage of the process as can the evaporator system. Early fall rains sometimes damage prunes being dried in the sun.

The prunes are dipped in a solution formed by dissolving a pound of concentrated lye in about twenty gallons of water. This is kept at the boiling point, and when the prunes are dipped into it the lye causes the tough skin to become tender, facilitating the escape of moisture from the fruit. The prunes are then rinsed in clear water, and in some cases are allowed to roll down an incline provided with many needle-like points which pierce the skin and hasten further the process of drying. The fruit is then placed on trays out-of-doors, or in the evaporators, after which it is allowed to stand for several days under conditions where escape of moisture will be much less rapid. It is then "processed"; that is, dipped in boiling water, or boiling water with glycerine added to it, or subjected to a steam bath. This sterilizes the fruit, cleanses it, and imparts a lustrous appearance. The product is then ready to be packed and shipped.

The curculio, plum gouger, aphid, and scales are among the most common insects infesting plum orchards. Crown-gall

or root-knot, black-knot of the branches, and leaf-curl are some of the diseases frequently occurring on plums. (See Chapter XVII.)

Most Japanese and some European plums are self-sterile. Single varieties of these self-sterile sorts should have rows of other kinds blooming at the same time planted with them. If a self-sterile variety is planted alone in an orchard, it will not, of course, bear fruit.

282. The cherry was common in Greece as early as 300 B. C. Pliny states that it was brought to Rome about 60 B. C. From the sweet and sour cherry of the Old World, the cultivated varieties were developed.

The sweet cherry is a tall tree, wild in Europe and central Asia, and the cultivated forms are likewise strong upright growing trees. The sour cherry is a shrub, wild in Asia Minor and perhaps in southeastern Europe, and the cultivated form is a rather small spreading tree or tall shrub. Among prominent varieties of the sweet cherry are the Advance, Lewelling, Bing, Burbank, Black Republican, Napoleon, and Tartarian; of the sour cherry, Morello, Richmond, and Montmorency.

In comparing the sour with the sweet cherry, U. P. Hedrick says:¹ "The sour cherry is very cosmopolitan, thriving in many soils; is able to withstand heat, cold and great atmospheric dryness, if the soil contain moisture; and though it responds to good care, it grows under neglect better than any other tree-fruit. The sour cherry, too, is rather less inviting to insects and fungi than most other stone-fruits, being practically immune to the dreaded San Jose scale. On the other hand the sweet cherry is very fastidious as to soils, is lacking in hardiness to both heat and cold and is a prey to many insects and subject to all the ills to which stone-fruits are heir; it is grown at its best in but few and comparatively limited areas, though these are very widely distributed."

¹ Hedrick, *Cherries of New York*.

This statement explains why the cultivation of the sweet cherry is so limited in North America. Its commercial production is confined to California, Oregon, parts of Montana, the Hudson Valley, western New York, and western Michigan in the United States; and in Canada to that part of Ontario along the northern shore of Lake Erie and to the interior parts of British Columbia.

The sour cherry is adapted over a much wider territory. It is grown extensively along Lakes Ontario and Michigan, and throughout the eastern and central states. In Canada sour cherries are produced mainly in Ontario, Nova Scotia, Prince Edward Island, Quebec, and British Columbia.

It is of interest to note that the seven leading cherry-producing states are: California, Oregon, Michigan, New York, Pennsylvania, Ohio, and Wisconsin. Very few cherries of any kind are grown in the South.

Nearly all varieties of sweet cherries are self-sterile; therefore, several kinds should be planted in rows in the orchard for pollination purposes.

The cherry, however, is primarily a home fruit and the greater part of the fruit raised in the United States is consumed on the farms where grown. The tree does not require specialized care, as does the peach. The sour cherry is remarkably resistant to insect enemies and plant diseases, and both the sweet and sour forms require little attention in the way of pruning after the framework of the tree has become well established. The tree also thrives with less attention to soil fertilization than do the other orchard fruits. On the other hand, many orchards large and small have suffered neglect because they do moderately well even under adverse conditions. With good care they would far more than pay for the increased cost of attention.

Those communities that excel in the raising of cherries give careful attention to cultivation, pruning, control of insects, fertilization, cover-crops, and harvesting; and the trees re-

spond in quantity and quality of fruit to the care which they receive.

It is interesting to note that the famous cherries of Japan have been developed for flowers, and not for fruit. *Prunus serrulata* and *P. Lannesiana*, the Japanese cherries, bear fruits about as large as a small pea, but the trees are of such striking appearance when in blossom that cherry flowering time is, in Japan, a time of especial festivity. "The sunshine that attends cherry blooming time in April," says one author, "the magnificence of the flower-laden boughs and the picturesque flutter of the falling petals inspired an ancient poet to liken the cherry to the 'soul of Yamato' (Japan), and it has ever since been thus regarded."

NUTS

283. The almond.—References to the almond in Biblical literature show that it has been known to mankind for many centuries. At present, wild forms are found in the Mediterranean region. Edible varieties, probably developed from the native wild forms, were early distributed over many parts of Asia, Europe, and Africa. They are now grown in large quantities in Spain, France, Italy, Palestine, and in certain tropical islands. Various kinds of almonds were introduced into the United States by the Department of Agriculture and by nursery firms. Tests disclosed the fact that the almond could be grown successfully only in a few sections. Commercial plantings are now found mainly in the valleys and foothills of California, where the warm dry climate is especially favorable to its production. Fully 80,000 acres have been planted, some of which have not yet come into bearing. The annual crop averages about 8,000,000 pounds. A few commercial orchards of almonds are located in Washington, Utah, Nevada, and Arizona, but in these states frosts in spring and freezing in winter make the almond an uncertain and unprofitable crop.

As the almond blooms very early in the spring (February 1 to March 20, depending on the variety and district), it is very likely to be injured by spring frosts except in the most favorable locations, such as the low foothill regions and somewhat elevated portions of the large interior valleys of California, where the air drainage is good and frost not likely to occur at blooming time.

All commercial varieties of almonds are self-sterile, insofar as they have been tested, and some have been found to be inter-sterile. The varieties for inter-planting and for pollination, therefore, must be selected very carefully.

The almond is propagated by budding upon almond or peach stocks. It thrives and produces best on deep well-drained soils. A moderate amount of moisture is necessary.

The California Almond Growers' Exchange is the principal marketing agency for almonds grown in this country. This coöperative organization is similar in its scope to the other farmers' coöperative agencies mentioned in Chapter XIX.

The almond is placed on the market both in the shell and as a shelled product. Almonds and almond paste are used in the making of many confections.

The almond tree is subject to few diseases or insect pests.

Crown-gall is rather common (see Chapter XVII) and shot-hole fungus sometimes appears. The latter is controlled by spraying with lime-sulfur solution. The most common insect pest is the red-spider, which multiplies rapidly in the hot summer months. Sulfur is applied as often as the red-spider becomes troublesome.

284. The walnut.—Black walnuts of one kind or another have been found in nearly every state and in parts of Canada. The Persian (English) walnut, has been tested in many sections of the United States, but did not thrive except in favored districts. It is now grown commercially in the Pacific states and especially in California. The latter state has approximately 75,000 acres of walnut plantings. On

account of the large size the trees attain, they are planted farther apart than are other orchard trees. They are propagated by budding or grafting the best varieties of Persian walnuts upon black walnut stock.

When the walnuts become mature on the trees, most of them drop and are picked up by hand. Those which do not drop are shaken from the tree by the use of poles with hooks at the ends. Many of the nuts drop free of the hulls and those which do not are hulled by hand or are run through a revolving cylinder which removes the hulls readily. The nuts are left to cure in trays or in well-ventilated drying bins for a few days. After the curing process, the nuts are sorted and are bleached by being run through a bleaching solution. They are then graded according to size and are ready for marketing. Most of the Persian walnut crop in this country is placed on the market by a coöperative association of growers known as the California Walnut Growers' Association.

Blight is a common disease affecting the walnut. This bacterial disease is especially destructive to the young and tender growth and to the nuts. When blight attacks the nuts early, they turn black and drop, and when it attacks them later their development is hindered. The walnut aphid is a troublesome insect pest. It is controlled by applying a nicotine dust preparation (made of nicotine dust mixed with finely powdered kaolin) by means of a dusting machine. In recent years the codlin-moth has been troublesome, the larva of which enters the nuts.

285. The pecan is native to the United States. Wild forms are found in several of the southern states in the Mississippi basin. From these a number of excellent varieties have been derived. The pecan has become one of the most popular of the nuts and the best varieties sell at good prices. It is planted widely in southeastern United States, the most extensive plantings being in Georgia, Alabama, and northern Florida. As pecans do not come true to seed, the

trees are propagated by budding or grafting upon seedling stock. "A deep, fertile soil, sufficiently porous to admit of free root growth, well-drained yet by no means dry, is considered best adapted to pecan culture. Localities in which the water table is within reach of the taproot seem to be preferred by the pecan. It is essential that the trees be not allowed to remain in standing water for any length of time, although an occasional overflow to a depth of several feet apparently is beneficial rather than harmful."¹

The pecan rosette is one of the troublesome diseases, and the case-bearer is very damaging to some varieties in some seasons.

286. Other nuts.—The hazelnut is found in many of the cooler parts of the United States in its wild forms. The filbert is a related fruit; it has long been known in Europe. Many improved varieties of the nut are now grown in North America. Some extensive plantings of filberts have been made in the Pacific Northwest. Harvesting is done promptly as soon as the husks become brown. The nuts are spread out to dry, after which the husks are removed.

The pistache is a slow-growing tree which thrives in mild climates. De Candolle states that it is a native of Persia and Syria. In the United States it is grown principally in California and Texas. The small nuts are borne in clusters. The shells are thin, smooth, and tough. The kernels are green in color, have a pleasant flavor, and are much sought after by confectioners.

The well-known chestnut, which has been popular as a roasted nut and has been widely grown in the eastern United States, is rapidly disappearing owing to the destructive effects of the chestnut blight.

The hickories include, besides the pecan, the shagbark, shellbark, and pignut. All the species are slow-growing trees which require well-drained soils for their best development.

¹ C. A. Reed, *Farmers' Bull.* 700, U. S. Dept. Agric.

The hickories are widely distributed over the eastern, central, and southern parts of the United States.

EXERCISES

EXERCISE I.—Kinds of fruit grown.

Materials.—Orchard trees in your locality.

Procedure.—(1) Make a list of fruit-trees in your locality and classify them into deciduous and evergreen trees. (2) Visit a few of the leading orchards in your locality. Note the type of soil, irrigation, drainage, cultivation, fertilization, types of pruning, and so forth.

EXERCISE II.—Distribution of species of fruit.

Materials.—Large outline map of the United States, United States Department of Agriculture Yearbook, census reports, Cyclopaedia of Horticulture, atlases.

Procedure.—Look up the publications mentioned in the districts of the United States where certain fruits (in which you are especially interested) are grown and indicate the places for each fruit on the outline map. Read up in atlases the kinds of climate found in the different states in which the fruit is raised. Note the range of climate in which each fruit thrives.

EXERCISE III.—Plan for home orchard.

Materials.—Map-paper, notebook, T-square, drawing triangles, ruler.

Procedure.—(1) Draw a plan for a home orchard. Indicate the kinds of trees desired, planting distances, and the like. (2) Make a schedule of operations necessary for the care of this home orchard for one year.

EXERCISE IV.—Project. Look up in as many references as possible all the facts you can find in regard to the fruit you wish to select for your project exercise. Write an essay based on the facts thus learned as preliminary to your project.

CHAPTER XIV

SEMI-TROPICAL FRUITS

THE principal fruits grown in the subtropical sections of the United States are members of the genus *Citrus*. Olives and figs are produced in California and the South, and also a few other semi-tropical fruits of minor importance.

CITRUS FRUITS

The cultivation of citrus fruits on a commercial scale is a comparatively new horticultural enterprise in the United States. The oranges and lemons used in this country thirty years ago were imported almost entirely from Italy, Sicily, and Spain. In the year 1919, the value of the citrus crop in the United States was almost one hundred and fifty million dollars. Of this amount, two-thirds came from California, almost one-third from Florida, and a smaller amount from Louisiana, Mississippi, and Texas.

287. History.—De Candolle writes that, at the beginning of the Christian Era, the orange and its allied forms, with the possible exception of the citron, were unknown. These fruits grow wild in southeastern and southern Asia and were introduced to America by way of the Mediterranean. A few plants in America are related to the genus *Citrus*, but one must travel to the other side of the world to find the fruit in its native habitat.

From its original home it was carried first to India, and thence to Italy and Spain, where it is today grown in large quantities. From Europe it was brought to the West Indies, to South America and to Florida, forming the basis of

orange-culture there; and in 1872 two trees, the buds of which came originally from South America, were planted in Riverside, California. These two trees proved, on fruiting, to be a new variety, seedless, and possessing especially fine qualities. The good qualities were quickly recognized, and the fruit, named by the original growers the Washington Navel (Fig. 111), became the foundation for the industry in California.

It is especially worthy of note that this fruit, which originated in the tropics, possesses qualities when grown in the temperate zone of which it gave no hint in its original habitat. Not only is the fruit vastly superior in flavor, having a sprightliness and zest in marked contrast with the sweet

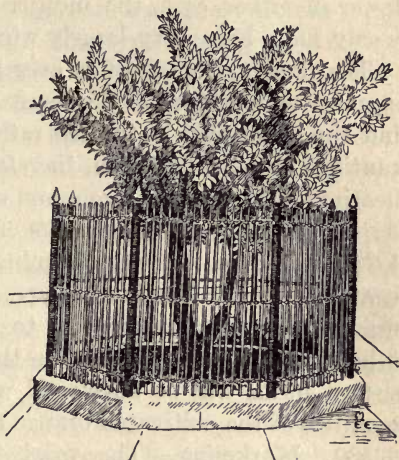


FIG. 111.—One of the parent Washington Navel orange trees still growing in Riverside, California.

insipid article of the tropics, but it has keeping qualities also that make it vastly superior for commercial purposes to the orange and lemon of warmer climes.

288. Frost.—The cultivation of citrus fruits in America has been attended by difficulties of many kinds. To begin with, these fruits came originally from the tropics, and tropical plants are, of course, extremely sensitive to cold. Tropical vegetables, such as the bean and the watermelon, are under successful cultivation, but they grow only during the summer and their sensitiveness to frost in the spring and fall is well known. The citrus tree must be protected during the entire year, for the fruit is still growing in the coldest parts of the winter. California and Florida, the former in 1913

and 1922, the latter in 1894, found by bitter experience by how narrow a margin of temperature these trees are kept alive. The cold was so severe that a large part of the crop was ruined and, in many instances, the trees were killed to the ground. Had the thermometer dropped a few degrees lower in either case, the industry in the states concerned would have been very largely wiped out.

The danger from frost is ever present. The orange will stand a temperature of 25 degrees without serious damage, but the lemon will be injured rather badly. Elaborate precautions have to be taken, therefore, in the way of orchard heating; and it is no uncommon sight in the citrus district, during the early morning hours of December, January, and February, to see the fires burning in thousands of orchard heaters of every imaginable type. Some varieties of Navel oranges are more susceptible to injury by frost than are others; and it is hoped that in the course of time more resistant forms will be developed which will retain the good qualities of the cultivated orange of today.

289. Marketing.—The marketing of citrus fruit has always been a perplexing problem. The greater part of the crop is shipped hundreds, in many cases, thousands of miles, and it has been necessary to devise an elaborate system of refrigerator-car service so that the fruit can be kept cool from the time it leaves the packing-house until the boxes are removed from the car in some distant part of the country.

Frequently the fruit colors before it tastes sweet and the United States Government and the coöperative marketing organizations, working together, have attempted to protect the consumer by insisting on a standard of sweetness which would be satisfactory to the person eating the fruit. The method by which this standard was established is known as the eight-to-one test. The fruit is considered ripe when there are eight parts of soluble solids in the fruit to each part of acid. The soluble solids are for the most part sugars, and

fruit which comes up to this standard is satisfactory from the point of sweetness to the average consumer.

290. Insect pests.—Orange and lemon trees are subject to the depredations of many insect enemies, but especially of that group known as the scale insects. Wherever the orange tree grows, scale insects of some sort are almost certain to be found in abundant quantity. The type causing most injury varies in the different localities, depending on climatic conditions and other factors. In Florida the chief pests are the white-fly, rust-mites, and scale insects. In California the red, black, brown, and citricola scales, and the mealy bug give most trouble.

291. Control of insects.—There are two methods of insect control; spraying and fumigation. Spraying is practiced most commonly in Florida, fumigation in California. The former is cheaper but needs to be repeated much oftener, and constant care has to be exercised not to injure the evergreen foliage of the tree.

The fumigation method, also, must be performed with great care. If the temperature is too low or too high, or if the atmosphere contains too much water-vapor, the foliage and fruit may be seriously injured. For this reason, the work is always done at night, and care is exercised at each step of the process to avoid possible injury to the tree.

292. Citrus canker.—In recent years there appeared in Florida a citrus disease of such serious nature that the aid of the United States Government was invoked to bring about its control. This was the so-called citrus canker. It is an exceedingly virulent disease, attacking not only leaves and twigs, but fruit and stems as well. In its efforts to control citrus canker, the United States Department of Agriculture maintained a rigid quarantine wherever the disease was known to exist, in order to prevent its spread to new localities; and all diseased trees were burned as soon as they were discovered. A large appropriation for carrying out these

provisions was supplemented by funds from several states. At the present time the work of control has apparently resulted in the eradication of the disease.

What has been said about the control of canker illustrates very well some fundamental features of disease control. Constant watchfulness, the destruction of diseased trees wherever practicable, and the maintenance of rigid quarantines, are the three means most likely to be effective in the case of all new diseases, especially if eradication is at all possible.

293. The future of the citrus industry.—A considerable acreage is yet available for citrus planting; but year by year, some localities prove to be better than others for the citrus fruits, and there is a slow but natural process of adjustment going on. This is mentioned because it is true not only of oranges but of other fruits as well. Under the spell of a temporary enthusiasm the planting of some type of fruit will be pushed far beyond the limits of the regions adapted to it; then will come adverse seasons; many plantings will be neglected and will perish, but a few in especially suitable locations will persist. Thus the industry is extended. The process is hard on those who are carried away by their temporary enthusiasms, to the loss, it may be, of all they possess.

294. The pomelo.—Even a brief discussion of citrus fruits would be incomplete without some mention of the pomelo, known commercially as grapefruit. The fruit is borne in clusters of three to twenty, hence perhaps its popular name. It was brought to Florida by the Spaniards in very early times, and at first was grown in gardens merely as an ornamental plant. It is only in the last quarter of a century that the pomelo has assumed commercial importance. This somewhat bitter fruit has proved both wholesome and appetizing, and has come to be widely used as a breakfast and salad dish. The Florida pomelos are preferred in the market, although a considerable quantity of the fruit is raised in California. Its

cultivation is similar to that of the orange, as are the marketing problems connected with it.

THE OLIVE

295. Although the exact origin of the olive is obscure, there is no doubt that it is one of the oldest horticultural possessions of the race. References to it in the Old Testament¹ show that the Hebrews early knew it as a domesticated plant. A myth of ancient Greece relates that in a contest between Minerva and Neptune as to which could give the most useful gift to man, Neptune gave the horse and Minerva the olive. Branches of the olive have been found in the ancient mummy cases of the Egyptians, and early Egyptian sculpture illustrates the manner of the extraction of olive oil.

The olive was brought to California by the early Spanish settlers. It was first known in the Mission gardens from which its culture spread gradually. In about 1885 a wave of enthusiasm for olive-growing swept the state, and from that time until 1900 extensive plantings were made. Some of these were in such unsuitable locations that they have since been dug up. At the present time the olive is grown commercially in California and in parts of Arizona.

The olive is such a thrifty grower that if the top is cut off new shoots will grow from the stump. The trees may attain a great age, sometimes living three hundred years. The olive is propagated easily by cuttings. It is more tolerant of poor and rocky soils than are other orchard trees, but produces maximum crops of best quality only where the soil is fairly good and the moisture moderately plentiful. The tree is an evergreen, keeping its foliage the year round. It blossoms late in the spring and is, therefore, not especially subject to injury by spring frosts. Hot dry winds, however, sometimes cause the blossoms to drop. Since the olives ripen on the tree

¹ Deuteronomy XXVIII, 40; Exodus XXIII, 11; Deuteronomy XXIV, 20.

in the late fall, they may be frosted at that time in unfavorable localities. In general, the olive requires a dry warm climate.

Olives are grown for pickling and for their oil. They are pickled either green or ripe. Certain varieties are better adapted than others for making the green pickles. The olives are picked from the tree by hand, soaked in lye solutions to remove their extreme bitterness, washed in water, and then immersed in salt solutions. Pickled olives are now put through a process by which they are heated to a high temperature under pressure, to destroy any injurious bacteria that may be present. Olive oil is secured by pressing the ripe olives. The oil which is obtained first is best in quality.

THE FIG

296. The fig, a native of the Persian Gulf region, has found a congenial home in the warmer parts of the United States. It is grown in the bush form where freezing is likely to occur, otherwise the tree form is preferred. Although the fig tree is adapted to a great diversity of land, heavy soils, retentive of moisture but well-drained, are best. Nematodes (a kind of small worm) are less likely to prove troublesome than in light sandy soils. The fig tree suffers greatly from lack of drainage and should not be planted in water-logged land. As fig trees are shallow-rooted, care in cultivation is necessary to prevent injury to the roots.

The fruit of the fig consists of an enlarged fleshy hollow receptacle, having its flowers on the inner surface. Figs possess three kinds of flowers: namely, pistillate, staminate, and gall flowers. Pistillate (female) flowers are, as a rule, the only ones present in the edible varieties. Staminate and gall flowers are found in the wild or caprifigs. The latter are really pistillate flowers modified to suit the needs of the fig wasps in laying the eggs and hatching their young. Most varieties do not require cross-pollination in order to produce

fruit, but the Smyrna fig does. For a long time attempts to grow this type in America failed because of lack of knowledge of the necessity of pollination and of the agency by which pollen from the wild figs was introduced through the small opening or eye of the Smyrna on to the stigmas within. It was finally learned that the transfer of pollen was effected by means of a tiny fig wasp. The insect lives its life cycle in the wild or caprifigs, and three crops of the wild fruit are necessary in order that there may be figs the year around so that the insects may not die out. The proper kinds of caprifigs must, therefore, be planted to insure fruit all year. To insure pollination of the Smyrnas, caprifigs containing the wasps are hung in wire baskets in the Smyrna trees when the figs are quite small. The female wasps, in crawling out of the caprifigs, become covered with pollen which sticks to their bodies. They then enter the Smyrna figs through the eye. The insects crawl around in the fruit looking for the short-styled gall flowers such as are found in the caprifig in which to lay their eggs, but finding nothing but the long-styled female flowers they finally attempt to lay their eggs in them. Meanwhile, the insects in wandering around inside the fig have rubbed off a large amount of the pollen adhering to their bodies upon the female flowers, and as a consequence of this pollination, fruit will set.

Smyrna figs can be grown only in hot dry climates, and will sour on the tree if the atmosphere is at all humid. They were formerly grown successfully only in a part of Asiatic Turkey and were shipped from the port of Smyrna, but after the discovery of the methods of pollination accomplished by the wasps, this best of all dried figs was widely planted in California and Arizona, where it is successfully grown in large quantities in the hot dry portions of those states. Harvesting methods and preparing for market are comparatively simple. The figs are allowed to fall to the ground when mature, are picked up by hand, dried, pressed, and packed for the market.

In warm regions where the air is too moist for the successful growing of the Smyrna or other white figs, dark figs are grown. Throughout the southern states, quantities of figs are produced, which are used and shipped fresh, made into preserves, or canned. Figs in the canned, preserved, and dried forms, are delicious and wholesome foods.

297. Other semi-tropical fruits grown in some parts of the United States are the guava, feijoa, loquat, jujube, persimmon, pomegranate, and avocado. Although all of these are produced to some extent, lack of space forbids a description of them in this book.

EXERCISES

EXERCISE I.—Citrus fruits.

Materials.—At least one each of the following fruits: Washington Navel orange, seedling orange, lemon, grapefruit.

Procedure.—Sketch each of the above fruits bringing out typical differences in size and structure. Note the oil glands on the surface of the fruit. Make a transverse section through the center of each midway between stem-end and apex. Make a sketch of this section showing the location of segments and the arrangement of cells within the segments.

Make another transverse section through the center of the Navel orange and sketch, bringing out similarities between the Navel and the original fruit. It may be mentioned parenthetically that the Navel is itself an orange within an orange.

In the drawings already made, indicate in the case of those fruits bearing seeds the points of attachment of the seeds. Note manner in which fruit was separated from the tree. Note especially the way the cut was made and see if you can detect any sign of decay about this cut.

EXERCISE II.—Comparative amount of acid in orange and lemon.

Materials.—Orange and lemon, glass beaker, two graduated burettes, standard alkali solution,¹ phenol indicator, lemon squeezer, wire strainer.

Procedure.—Extract juice from orange, strain out coarse materials, pour into burette, measure out 20 c.c. of juice, and add a few drops of

¹ To the Instructor: Make up standard alkali solution by adding 6.25 grams sodium-hydroxide to 1000 c.c. of water.

indicator. Fill other burette to zero mark with standard alkali solution, and add solution to the 20 c.c. of orange juice, stirring constantly until the color is permanently changed.

One c.c. of the solution neutralizes approximately 10 m.g. of citric acid. How many m.g. of citric acid are there in 20 c.c. of orange juice?

Repeat using the juice of the lemon, calculating again the number of m.g. of citric acid in 20 c.c. of lemon juice. How does the amount of acid in a given quantity of lemon juice compare with that in the same amount of orange juice?

What connection is there between this fact and the taste of each of the two fruits?

EXERCISE III.—Study of varieties.

Procedure.—Get in your neighborhood as many different types and varieties of citrus fruits as you can find. Arrange these in the class-room, being careful that each variety is named. Make a comparative study of the different fruits, recording in the notebook the essential facts regarding each one, such as size, color, shape, period of ripening, susceptibility to frost, commercial importance, and any other facts which may be ascertained.

EXERCISE IV.—Advertising citrus fruits.

Materials.—The leading national magazines.

Procedure.—Clip from magazines all the advertisements you can find dealing with citrus fruits. Make a study of these advertisements, noting especially their general appearance and their timeliness, from the standpoint of household use and of crop production.

It is said that the citrus interests of the country are among the heaviest magazine advertisers. Notice how many advertising pages there are in the periodicals you are examining and calculate the percentage of the whole contributed by the citrus advertisers.

EXERCISE V.—Citrus projects.

Procedure.—All students having citrus projects should at this time prepare a detailed statement regarding the care of the project and its financial condition. This should be presented to the class in the form of a written and oral report.

CHAPTER XV

SMALL-FRUITS AND THE GRAPE

IN every locality and in nearly all gardens, some kinds of small-fruits may be grown successfully. Whether strawberries, raspberries, blackberries, loganberries, dewberries, currants, or gooseberries are raised, the yield to the square rod, under favorable conditions, is astonishingly large.

THE STRAWBERRY

298. Origin and adaptation.—The origin of the strawberry has not been traced, but there are records of its cultivation in England in 1483, and of the appearance of improved sorts in the eighteenth century. About 2000 varieties of cultivated strawberries have been developed in North America. The improved American kinds have been introduced into Europe.

Since the strawberry is adapted to a wide range of climate, it is grown for home use and local market in nearly every region in the United States and Canada. The principal areas of commercial production are near the large cities of the northern states, along the Atlantic Coast, in the Mississippi Valley, and in parts of the Pacific states.

299. Soils.—The strawberry requires an abundant supply of water and a climate which is not too hot nor dry. When these conditions are present, it will grow on many types of soils, although a rich loam is most favorable. Heavy manuring is usually desirable. As the strawberry plant is a shallow feeder, it can be grown on soils underlaid with hardpan if the drainage is satisfactory.

300. Starting the plants.—As stated in another chapter, strawberry plants are propagated by means of runners. In starting a new bed, young plants should be used rather than old ones whose roots have become dark. Only strong and healthy individuals with good root systems should be set out. The roots should not be allowed to dry out. This may be avoided by keeping the plants in mud from the time they are dug until they are transplanted. When shipped from a distance, the roots are kept from drying by a packing of slightly moist sphagnum moss or similar material. It is customary before planting to remove some of the leaves and to prune the roots to about half their normal length. It is very important that the plants be set so that the crown is level with the soil. Care should be taken not to bury the crown or to set so high that the upper roots are exposed (Fig. 112). Failure to grow is frequently due to the plants not being set at the proper depth. A cultivated crop should be grown before land is used for strawberry plants in order to avoid injury to them from grubs which inhabit sod or grass land.

301. Planting systems.—There are several planting systems for strawberries, each of which has its advantages. In the matted-row method (Plate VII), the plants are set about eighteen inches apart in rows at least four feet distant. The plants are allowed to run together in narrow rows, and are prevented by cultivation from running across to the other rows. This system has the advantage of producing a large number of plants on a given area, but the berries are not as large as with some of the other methods.



FIG. 112.—Proper depth to set strawberry plants.

The hedge-row system is popular in some sections. The plants are set as described for the matted-row, but for each plant only one runner on each side is allowed to take root in the row, while all other runners are removed. In this method the plants are rather close together in the row, but have more room than in the matted-row system. In the hill system the plants are usually set at two-foot intervals in rows from three and one-half to four feet apart. The plants are cultivated both ways and are not allowed to produce runners. The largest berries are obtained when this system is used, but the total yields are smaller than under the other methods.

302. Cultivation.—After the plants are set out, they should have plenty of moisture. Frequent cultivation of the soil is necessary to conserve the moisture, and irrigation is commonly resorted to. The plants are not allowed to bear fruit the same season as set, but the blossoms are picked so that the strength, which would otherwise be used in developing fruit, goes to produce a thrifty growth. The plants are not allowed to bear more than two or three years, and, since after that period the berries become unprofitably small, the bed is plowed up and a new one started elsewhere.

303. Mulching.—In cold climates, clean straw free from seeds or weeds is put over the plant to prevent injury from freezing. The straw is left on until the following spring when it is raked between the rows and finally removed after the berry crop is harvested. Where insect pests are troublesome, the tops are cut with a mower, allowed to dry thoroughly, and burned with the straw in the rows. This will not injure the plants as they will put forth new leaves. If the mulch is left in the rows late in the spring, it retards the blossoming several days, and so may prevent the blossoms from being injured by frost.

304. Pollination.—In setting out strawberry plants, it should not be forgotten that some varieties are pistillate only and require other kinds for pollination purposes.¹

¹ See Chapter XII.

305. Harvesting and packing.—The picking of the berries at the correct time and proper packing of them are essential to commercial success. Strawberries are graded as they are picked, and are placed in quart, pint, or half-pint boxes. Sometimes the berries of the top layer are packed obliquely in the box with the stems downward and the tips all pointing one way. Fancy packs of this sort bring a better price in certain markets than the ordinary packages. In the picking, strawberries should not be pulled from the calyx, but the stem should be pinched off so that a small portion is left with the berry. Berries to be sold in the local market can be picked quite ripe, but those to be shipped must be slightly green. Some varieties ship better than others. Advice as to the best varieties to grow in any particular section can be obtained from local nurserymen, and from the state experiment stations.

306. Insects and diseases of the strawberry can be controlled by rotation of crops, burning, and spraying.¹

307. Everbearing strawberry.—Of late years much interest has been shown in everbearing strawberries. This sort bears fruit more or less continually from the usual time in early summer until frost kills the blossoms in the autumn. They bear especially well during the fall months. Everbearing strawberries are of special value in frosty localities, for although frost may kill the early blossoms of the season, more will be produced later, as is not the case with the ordinary kinds. The everbearing strawberry is usually grown in matted rows. Its culture is the same as for the other kinds.

THE BLACKBERRY

308. Origin.—The common blackberry grows wild in many parts of the country. Formerly most of the blackberries were obtained from the wild, but with the increase in

¹ For a detailed account the student is referred to Fletcher's *Strawberry-Growing*.

population and the destruction of the wild patches to make room for farms, the cultivated blackberry came into prominence. These are as good in flavor and are superior in size to the wild berries. Of the cultivated forms there are many varieties.

309. Requirements of the blackberry.—The blackberry succeeds in nearly all sections of North America except the very coldest. Even there it can be grown if given proper winter protection. In hot dry regions the fruit will be small in size and scant in quantity, but may be improved greatly by irrigation. The blackberry thrives in heavy well-drained land, but will succeed in many types of soils if not too wet. While blackberries prefer rich soils, and while the proper addition of manure or other fertilizers increases the yield, too much fertilizing or too rich land make the growth of the vines undesirably rank.

310. Propagation.—Blackberries may be propagated by means of suckers or by root-cuttings according to methods described in the chapters on propagation.¹

311. Planting and training.—Blackberries should be given plenty of room. They are usually planted from five to seven feet apart, in rows from six to twelve feet distant, according to the variety and system of training. The young vines should have the terminal shoots pinched back in the spring as soon as the plants reach a height of two or four feet. This causes stronger growth and greater stockiness. When the laterals reach a length of eighteen or twenty-four inches, they are pinched back. As the fruit is borne on the previous season's growth, all the old canes should be cut out after fruiting, leaving from three to six canes of the present season to bear fruit the following year. Blackberry vines may be grown without support, may be staked, or grown on a trellis, depending on the preference of the grower, the locality, and

¹ Chapters IV and V.



Plate VI.—Prolific bearing of the quince.

the variety. The trailing kinds, grown on a trellis or other forms of support, are usually kept cut back to ten or twelve feet in length.

312. Pollination.—Most of the blackberries are self-fertile but a few varieties are self-sterile.

313. Cultivation.—Blackberries require frequent cultivation. Some growers plant cover-crops between the rows where the climate is humid, or an abundance of irrigation water may be obtained. Cultivation of blackberries should be shallow so as not to injure their roots. Injured roots produce large numbers of suckers, which become troublesome.

314. Picking and shipping.—Blackberries picked green do not ripen well in shipment. The best quality of fruit is that picked ripe for local use. In picking, packing, and shipping, care is necessary. Unlike most fruits, blackberries do not ripen in storage. Blackberries may be eaten fresh, canned, or dried; or the juice may be extracted and used as a drink.

315. Winter protection.—In cold climates, blackberry vines are protected from freezing during the winter by being bent over and covered with soil in the fall. In the spring the covering is removed and the vines straightened out.

316. Special varieties of blackberries.—The evergreen blackberry, popular on the Pacific Coast, is said to be unusually resistant to disease. It is a trailer propagated by tip-layering. The Himalaya blackberry bears a late crop extending over a considerable period of time. It is a rampant grower and produces abundantly, but is adapted to certain sections only. The dewberry is a trailing variety of blackberry. It does well on almost any type of soil. Like the common blackberry it may be propagated by root-cuttings, or like the evergreen blackberry, by tip-layering. The loganberry was originated by J. H. Logan, of Santa Cruz, California. It is large, shaped like a blackberry, and colored like a red raspberry, and has a distinct and pleasant flavor of its own. This fruit may be canned or dried and its juice makes a very fine

beverage. It thrives and is grown extensively in the Pacific Coast states, but will not succeed in cold climates. The loganberry is propagated by tip-layering, is trained on some form of trellis, and is cultivated in the same way as the blackberry. The phenomenal berry is somewhat similar to the loganberry. Since localities where it will succeed are limited, it is not cultivated extensively.

THE RASPBERRY

317. Among the raspberry types are the red, black, purple, and yellow. The red raspberry propagates by suckers so readily that it is likely to become a nuisance. On this account, many growers plant in hills and cultivate in both directions. Red raspberries are propagated commercially by root-cuttings. Black raspberries, or "black-caps," are multiplied by tip-layering. The yellow and the purple varieties may be propagated by either or both of the methods just mentioned, depending on the variety.

All types of raspberries succeed best in cool climates, continuous hot weather being very unfavorable. They require thorough cultivation and plenty of moisture, but the land should be well drained. They succeed on a wide range of soils.

Although some of the red raspberries tend to produce fruit in the autumn on the same season's growth, for practical purposes the fruit of all varieties may be said to be borne upon growth of the previous season. Therefore, old wood can be cut out after fruiting or early in the following spring. It is customary to head the young wood of the black raspberries back to a height that will cause stocky, well-branched, fruitful plants. This should be done with red raspberries also in most cases.

CURRANTS AND GOOSEBERRIES

318. **Adaptation.**—Both currants and gooseberries thrive in cool climates. They withstand intense cold and survive

long severe winters. In hot or dry regions they will not succeed. As currants and gooseberries blossom very early in the spring, attention must be given to air drainage. They should not be planted on low places where the cold air is likely to settle. Both of these plants grow best on heavy and moist, but well-drained, soils. Northern slopes are generally preferable. Currants and many kinds of gooseberries are propagated by cuttings. Those varieties of gooseberries which do not grow well from cuttings are propagated by mound-layering. (See paragraph 78.)

319. Bearing habit.—Black currants bear best on one-year-old wood. In pruning it is customary to cut out all wood which has borne two crops, thinning the center. Six or seven canes are left on each bush.

Red and white currants bear fruit on spurs on the old wood and at the base of one-year-old growth. They bear most fruit on wood younger than four years. Pruning one-year-old red or white currants consists in removing all but six or seven of the strongest shoots. In the following year, about eight shoots are left, half of them being two years old, and the other half one year old. The third year's pruning consists in cutting out all shoots except two or three each of one-year-old, two-year-old, and three-year-old growth. The following years, all stems older than three years are removed, leaving enough one-year-old stems to take their places.

With gooseberries the fruit is borne on one-year-old wood, and on one-year-old spurs upon older growth. The early pruning of the gooseberry is similar to that of the currant. In the later pruning, all stems which have produced fruit two years are removed, except in the Pacific Coast states where it is customary to allow the stems to bear fruit for three years.

320. Cultivation of currants and gooseberries is similar to that given other bush-fruits. Cultivation should be shallow so as not to injure the roots.

321. Insect pests and diseases. — The currant-worm, currant-aphis, and currant-borer are common pests. The first may be destroyed by arsenical sprays (one pound powder, or two pounds paste of lead arsenate to fifty gallons of water) applied at the proper times to kill the larvæ. Nicotine-sulfate spray is used to kill the currant-aphis. Borers are difficult to reach. The only practical way is to cut out and burn the infected canes. The San Jose scale sometimes is troublesome on both currants and gooseberries. The remedy is lime-sulfur spray of winter strength, or oil emulsions applied while the plants are dormant.

Anthracnose is a common disease of the currant and gooseberry, as well as of other bush-fruits. It is a fungus, which first appears as brown spots on the upper surface of the leaves, and later makes the leaves turn yellow and drop. The disease attacks the canes and fruits. A spray of lime-sulfur applied while the plant is dormant is helpful. Applications of bordeaux mixture are made during the growing season. The application of lime-sulfur or bordeaux is useful in controlling other leaf-spot diseases.

Mildew, another common disease, can be controlled by application of sulfur.

Cane-wilt in the currant is rather serious as it is difficult to control. The disease enters at the buds and works down the stem, causing the fruit and leaves to die. The best treatment is to cut out and burn diseased canes. Bordeaux mixture applied in the growing season is recommended.

In white pine blister-rust the fungus first starts on currant or gooseberry leaves, and then attacks pines. It finally kills the trees. The disease cannot be spread among the pines without the aid of currant or gooseberry bushes as a host plant. In localities where the disease is present, no attempt should be made to grow currants or gooseberries within a considerable distance of white pine trees, and all wild gooseberry or currant bushes should be destroyed.

THE GRAPE (Plate VII)

322. **Origin.**—The grape is generally credited to the Phœnicians. These tradesmen and sailors probably introduced it into the countries that border the Mediterranean. It is known that this occurred more than three thousand years ago; for Hesiod, writing about that time, describes the vine and gives directions for its care. But the cultivated grape did not originate with the Phœnicians. They in turn received it from other peoples, probably from the region of the Caspian Sea. De Candolle thinks that the forms found there represent the wild progenitors from which the domesticated *Vitis vinifera* has sprung. This is the grape of history. In this country, it is confined mostly to California.

323. **The grape in Europe and America.**—The grape has been used in Europe from earliest times primarily for the making of wines. Hundreds of varieties are cultivated in that part of the world at the present time, but all are descended from the single species, *Vitis vinifera*, which is the wine-producing form. The American table grape is another product, and is derived either directly from native American species, or from hybrids secured by crossing these with the European forms. The early settlers in America found the grape growing wild in great abundance; but so accustomed were they to the European point of view that they thought of it only in terms of the wine which might be made from it. About the middle of the last century, however, the discovery of the Concord grape marked the beginning of a new era of American grape-culture, founded on a native American variety.

324. **Origin of the Concord.**—In his work entitled *The Evolution of Our Native Fruits* Bailey gives a full account of the types of grapes that have originated in America. In speaking of the Concord, he says: "Mr. Ephraim W. Bull bought the house at Concord, in which he lived, in 1840. That year, he relates, boys brought up from the river some

wild grapes, and scattered them about the place. A seedling appeared, evidently the offspring of these truant grapes. Mr. Bull tended it, and in 1843 he obtained a bunch of grapes from it. He planted seeds of this bunch, and a resulting plant fruited in 1849. The fruit had such merit that all other seedlings were destroyed. The new variety was named the Concord. . . . It is the most important type of American grapes, and the really successful commercial viticulture of the country dates from its dissemination; and yet this grape is a pure native fox-grape, and evidently only twice removed from the wild vine."

325. The grape industry.—Grapes of one kind or another grow wild in all parts of the United States, and in sections of Canada and Mexico. The cultivated forms, also, find congenial conditions in widely separated areas of the continent. A large industry has grown up in the province of Ontario. New York contains several centers of note, especially the lower Hudson Valley, and the Lake region in the central-western part of the state. Extensive vineyards are located in Michigan, and in the Ozarks of Missouri and Arkansas. There are also some plantings in Alabama and Georgia. Those portions of Ohio, Pennsylvania, and New York bordering on Lake Erie have long been noted as grape-growing regions and there are extensive plantings in the interior valleys of California.

326. Propagation, planting, and care.—The grape is propagated from cuttings of ripened wood of the preceding summer's growth. These cuttings may in exceptional cases consist of a single eye, planted in sand much as if they were seeds; but this method is resorted to only in the case of very valuable plants where rapid increase in number is desired. Ordinarily, the cuttings are from eight to eighteen inches in length; the longer ones are for very light open soil that is likely to dry out to a considerable depth, the shorter cuttings for the relatively heavy and retentive soils. In those sections

of the country in which the grape root-louse must be taken into account, the grape is grafted on some form of resistant American stock. The cuttings are usually rooted in the nursery, but sometimes they are set out directly in the field. Distance of planting depends on variety and local conditions. The most common is eight feet each way.

The grape comes into bearing in about three years. It is a healthy vigorous plant, and will continue in profitable production for many years if given careful and intelligent attention. There is a constant struggle, however, between the wood-growth and the fruit-growth tendencies of the vine which is much more pronounced than is the case with most orchard fruits. The only way by which this can be regulated is by proper pruning; and this, therefore, becomes of supreme importance in grape-growing.

327. Grape pruning.—In discussing the pruning of grapes, the following terms are commonly used: (The letters refer to Fig. 113.)

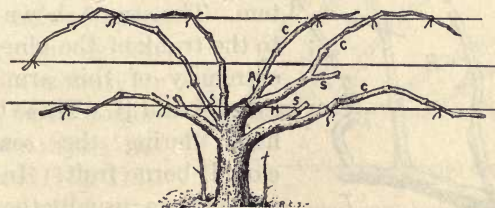


FIG. 113.—A grape-vine pruned and tied by the long-cane system.

Trunk—the main body of the vine.

H. Branch—a principal division of the trunk.

A. Arm—a division intermediate between branch and cane.

C. Cane—a ripened shoot.

Shoot—a growing leafy branch, the wood of which is not yet matured.

S. Spur—a cane cut back to a stub containing one to four eyes.

Adventitious bud—a bud arising from undifferentiated tissue.

Water-sprout—a sprout growing from an adventitious bud above the surface of the ground.

Sucker—a similar shoot starting below the surface.

Since the primary object in pruning is to secure a maximum yield of choice fruit, the first question which naturally arises is where the bunches of grapes are found on the growing vine. These bunches are not borne on old wood. They are not on shoots which arise from wood more than two years old. That is, there is no fruit on water-sprouts or suckers. The fruit occurs on shoots arising from buds on canes of the previous season's growth. As a rule, the first, second, and third nodes of the shoot indicate the points at which the bunches of grapes will develop, though sometimes they are found farther out.

For those vines which bear their fruit in the lower nodes of the shoot, the method of pruning used is called the spur or short system, while in the case of those varieties which bear the grapes farther out on the shoot, the cane or long system is the one employed.

328. Spur-pruning.—For the European vinifera grape,

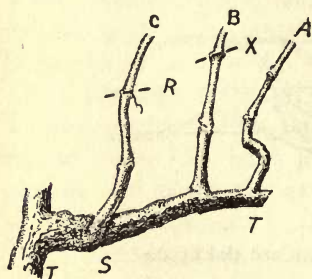


FIG. 114.—Unit of short pruning of the grape.

Fig. 114 illustrates the spur system. The arm is shown attached to the trunk of the vine. At the extremity of this arm are two canes A and B. These two canes have, during the season just closed, borne fruit. In pruning, one of them, usually the outer, or A, is removed entirely. The other, B, is cut back to two or three or four eyes, for example at

the point X, leaving a fruit-spur of one, two, or three buds. When growth starts on this spur, shoots will develop from each of these buds; these shoots will bear fruit, and they will in turn be treated next year as A and B have been treated this season.

Year by year the fruit-bearing portion of the arm gradually extends outward as can readily be seen. It is necessary for cultivation and other reasons to keep this arm shortened to

within reasonable limits. The way in which this is done is indicated in the drawing. It will be noticed that there is another cane growing from the point close to the lower end of the arm, labeled C. If the arm becomes too long, C will be allowed to develop as indicated and at the end of the first season of growth will be cut back to the point R, new shoots being secured from the buds below R. The arm can then be cut off at the point S and the portion of C below R becomes a replacing spur. The purpose of the latter is to shorten the arm.

The number of arms on a vine is determined by the variety, climatic conditions, especially rainfall, and by richness of soil. Where conditions are such as to induce greater growth, the plant can support more arms. When conditions are the reverse, the number of arms must be reduced.

329. Cane-pruning.—In this method the cane is not removed as in the case of spur-pruning, but is left either in its entirety or cut back much longer. The figure shows the method used (Fig. 115).

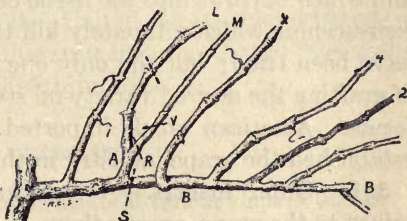


FIG. 115.—Unit of long pruning of the grape.

A is a spur which the year before was cut back to the line indicated at V. At the same time, cane B was left unpruned, meanwhile, B has produced a number of laterals, X, 4, 2. These have borne fruit. A has produced two canes from the two eyes of the spur. These two canes are indicated as L and M. This vine is now ready to be pruned. B will be entirely removed along the line S. Cane M will be retained next year in exactly the same way that cane B was kept last year, being headed back at some point as indicated by the drawing at the point B. Cane L will become a spur probably with two eyes, just as A was treated the year previous. M will now develop

laterals as B did, previously, and L will develop two shoots as A did in the previous season.

Next year's pruning will consist in removing M at R and the two canes of L will be treated as are the two canes of A. Thus the process is continued year by year.

330. Phylloxera.—The most destructive insect enemy of the European grape (the American species are immune) is the phylloxera, or root-louse. It was unknown in Europe until about 1855 when it was introduced into France on stock imported from America. At first it manifested itself in a few isolated localities only; but soon spread from vineyard to vineyard and from section to section, until in the year 1888, injury directly due to it was estimated at two billion dollars. The cause was found to be a very small insect, which can be distinguished only with the aid of a hand-lens, and which burrows into the tissue of the root, causing galls or excrescences which ultimately kill the vine. Many remedies have been tried; but the only one that is successful is that of grafting the desired variety on stock of resistant American forms. American stock imported into France finally re-established the grape industry in that country.

331. Other insects.—A number of other insects cause injury to the grape, among them, the vinehopper, root-worm, grape-beetle, cutworm, grape-curculio, sawfly, root-lover, and grape-vine sphinx. Each has been studied and information concerning methods of control can be found in the publications of the experiment stations.

332. Raisins have long been used as human food. They are mentioned several times in the Old Testament¹ and other writers, ancient and medieval, bear witness to their popularity. Until the development of the raisin industry in California within the last few years, they were produced solely in a few countries about the Mediterranean. California is now forging ahead in the commercial production of raisins.

¹ Numbers VI-3; I Samuel XXV-18; XXX-12.

They are not dried on the vine as is the case in countries where labor is cheap, but are picked and dried on trays. To hasten the evaporation process, the grapes are dipped in various solutions. They are then stacked or piled to produce sweating. Stemming and seeding are done entirely by machinery.

Efforts to grow the Sultana, a Smyrna seedless variety, met with indifferent success. The variety seems to revert to a seeded form whenever removed from its native habitat. A California variety has now been secured, the Thompson's Seedless, or Sultanina. This has proven to be superior to the Sultana in almost every respect.

Zante currants, known also as English currants, are in reality a type of raisin. They are the products obtained by drying a small black grape called the Corinth, which grows in Greece and some of the islands adjacent to it. Efforts have been made recently by the United States Department of Agriculture to introduce this fruit into the United States and the result will be awaited with interest.

EXERCISES

EXERCISE I.—Study of bearing habits of various kinds of berries.

Materials.—Small patches of plants of as many kinds of berries as possible.

Procedure.—(1) Study blossoms of as many kinds of the small-fruits as possible. Note their arrangement, size, and structure. What is the age of the wood upon which the blossoms are borne? Are the flowers perfect or imperfect?

(2) Examine berries of as many bush-fruits as possible. Study their structure. Note where they are borne. State the relation the bearing habit of each kind of bush-fruit has to pruning.

EXERCISE II.—Study of commercial methods in berry production.

Materials.—Berry farms in your locality.

Procedure.—If possible visit berry farms in your locality. (1) Make a list of favorable and unfavorable factors present for the growing of the berries. (2) Study and report on the methods of harvesting and

marketing various kinds of berries. What factors enter into the successful marketing of berries? Suggest if possible, improvements on the systems now in use in your locality. (3) Secure as much data as possible on the following for a number of kinds of berries: (a) Cost of bringing an acre of the plants into bearing; (b) cost of all cultural operations, harvesting, marketing, and the like; (c) yields.

EXERCISE III.—Project: The growing of small-fruits is an excellent project for the student, especially if arrangements can be made to continue the work for more than one season.

EXERCISE IV.—Grape cuttings.

Materials.—Canes of varying lengths; small sharp pruning shears.

Procedure.—Make cuttings from canes, being careful that the lower cut is just below a bud and the upper cut is just above a bud. Have these cuts of different lengths, from eight to twenty-four inches. Divide the cuttings into two groups, having an equal number of each length in each group. Place one lot in the ground so that they stand perpendicular or nearly so and with two buds exposed above the surface. Leave them here until they are well rooted. Place the others side by side in a pit partially filled with sand; then cover with sand to a depth of six inches or one foot and leave them until the ends have become callused. After callusing plant the cuttings in the ground as in the case of the other cuttings. Note results in each case.

(It is sometimes an advantage to callus cuttings in this way to avoid drying out.)

EXERCISE V.—Leaf characteristics.

Materials.—Leaves from different varieties of cultivated grapes and if possible from grapes growing wild in the neighborhood.

Procedure.—Make drawings of as many different leaves as you have available, noting especially the characteristics of those forms which have been imported from the Old World and of those which are known to be indigenous to America or closely related to native wild grapes. The student can ascertain the probable origin of the different varieties in such books as Bailey's *Standard Cyclopedia of Horticulture* or *Evolution of Our Native Fruits*.

EXERCISE VI.—If the student has a grape project, he should prepare and give before the class a full account of it, giving such data as size of project, age of vine, varieties, methods of pruning, time of pruning, cultural treatment at different seasons of the year, probable yield, value of crop, and all other topics concerning which he has information.

CHAPTER XVI

INSECTS AND THEIR CONTROL

OF all the problems with which the horticulturist has to contend, that of insect control is one of the most insistent and baffling. From the time of plagues of locusts described in the Old Testament to the present moment, insect depredations have not ceased to be a menace to human welfare in every country. Sanderson gives some illuminating figures regarding insect injury in the United States. He says that cereal crops probably suffer a ravage amounting to three hundred millions of dollars; hay crops are injured to the extent of sixty-five millions; cotton suffers from the boll-worm and other insects to the extent of eighty-five millions; fruits are diminished in value fully 20 per cent each year, making the total approach very close to thirty millions. The forests suffer very severely, probably over one hundred ten million dollars annually; live-stock products, three hundred millions; stored goods of various kinds, two hundred millions; truck crops, one hundred fifty millions. In addition to these, the injury to various incidental crops brings the total loss in one year to a figure well over one billion dollars. In addition to these losses caused by injury, vast amounts are spent each year on control of one sort or another.

333. The insect.—The technical name of insects is Hexapoda. The word indicates the basis on which they are separated from the remainder of the animal kingdom, for *Hexa* means six, and *poda* feet. An insect, therefore, is simply a six-footed animal. The spiders, which are ordinarily associated with insects, are different in that they have eight feet instead of six.

The insect structure is peculiar. The body is divided into three parts, head, thorax, and abdomen. The skeleton, instead of being a bony framework within the body as is the case with the higher animals, is a shell-like covering outside of the body; this is known as an exo-skeleton, from the Greek *exo*, out. Each insect is provided with two pairs of wings¹ and a mouth modified either for biting or sucking. The internal structure is highly complex. There is a circulatory and a digestive system, and an arrangement for breathing that is wholly unique and very interesting. This breathing system consists of ducts situated behind and below the wings, and connected by small tubes with the outside of the body. As the wings move, air is introduced into and expelled from these openings, thus supplying the insect with the oxygen necessary. One peculiar fact is that some insects may keep these openings closed for a long period; and this adds to the difficulty of their control. Beetles left for days in an atmosphere containing deadly cyanide gas will seem dead when taken out, but frequently, after a period of hours, will revive and crawl away uninjured.

334. Insect groups.—Flies are distinguished by having apparently one pair of wings only. From this fact they derive their technical name, *Diptera*, from two Greek words, *di* meaning double, and *ptera*, wings. If the fly is examined closely, a pair of stubs one-fourth inch or less in length will be found beneath the wings and attached to the back. These stubs are really rudimentary wings; so that while the fly appears to have one pair of wings only, it really has two. The butterfly and moth group is distinguished from others by the scale-like covering on the wings; hence the name, *Lepidoptera*, from *lepidō*, a scale. The group is subdivided into two smaller divisions, butterflies and moths. The former have three distinguishing characteristics; when at rest their wings remain poised in the air, the antennæ or “feelers” are

¹ There are some exceptions to the rule.

clubbed at the end, and the members fly in the daytime only. Moths, on the other hand, have unclubbed antennæ, fly at night, and fold the wings over the body when at rest. Hymenoptera include bees and wasps. Coleoptera, which comprise beetles, are very numerous in the animal kingdom, containing more individuals and species than any other known division of animals. Coleoptera are distinguished by the existence of two unlike pairs of wings, the under pair being used for flight, while the upper pair is differentiated into a hard shell-like protective covering. The Orthoptera constitute one of the best known of all the insect divisions, including such well-known types as the grasshopper, katydid, and locust. Historically, this group was one of the first to come under general observation, and it has been one of the most baffling as regards control. Homoptera include plant-lice, technically known as aphids, and scale insects. Every orchardist has come into contact very intimately with this last group for they are among the most injurious known and the most difficult to control.

335. Metamorphosis.—During its life process, the normal insect undergoes a number of changes. As a rule, it starts as an egg, hatches out into the larval or worm form, then enters what is known as the pupal stage, in which it is dormant for a time, and from which it finally emerges a full grown or adult insect. This process is known as metamorphosis. It is made clear most easily by a study of one or two specific examples.

336. Some examples of metamorphosis.—The butterfly lays its eggs and these hatch into caterpillars. The caterpillar feeds on vegetation of various sorts, growing rapidly the while. Finally it spins about itself a cocoon and becomes what is generally known as a chrysalis. It may remain in this form a few days or several months, depending on circumstances; but finally it assumes the adult shape and emerges as a full grown butterfly. The cycle is then repeated.

There are no essential differences in the case of the fly except that the forms vary somewhat and are given other names. The larval form, which in the butterfly is known as the caterpillar, in the fly is called the maggot. This maggot forms a cocoon as in the case of the butterfly and the adult insect emerges from it. In the case of the grasshopper, the caterpillar and chrysalis stages are replaced by a form known as the nymph which undergoes a series of molts, changing form slightly in each molt. The young of the grasshopper is quite strikingly different from the mature form, especially as regards relative sizes of head and body. This form gradually changes from molt to molt until in the final molt the adult insect appears.

337. Reasons for metamorphosis.—The purpose of this wonderful series of transformations is, in a word, to tide the insect over unfavorable food and weather conditions and is, therefore, a means whereby the survival of the species is accomplished. For example, in the winter when food and weather conditions are unfavorable, many insects are quiescent in the egg, and others in the pupal form. In the spring when weather and food supply become improved, the quiescent forms give place to the more active stages of larva and adult.

338. Mouth-parts.—Insect life is characterized by some very complex variations as regards mouth-parts. In some insects the mouth is adapted to a biting process, and these secure their food by eating the leaves and tender parts of the plants, often entirely destroying the tissue. In other insects, on the contrary, as in the butterfly, the mouth-parts are long tubes specialized for sucking. Such insects have no facilities for breaking or tearing the tissue of the plant, and so secure their food by drawing it up through this tube. Some of them, like the butterflies, suck the nectar from flowers; others, such as the aphids and scale insects, pierce the tissue of the plant and extract the juices from it.

• This difference as regards method of securing food has a very intimate relation to the whole question of insect control. In the case of insects with biting mouths, it is possible to kill them by placing poison on the surface of the plant; for they eat the leaves and tender parts of the plant in their entirety. Many of the leaf-eating beetles and other insects of this type are controlled entirely in this way. When insects subsist by sucking, this poison method is, of course, of no avail. Since the insect does not eat any of the surface tissue of the plant, other means have to be resorted to. The so-called contact sprays which kill because of their action on the body of the insect are employed here.

The active agent in most contact sprays is kerosene or distillate. It is, of course, entirely out of the question to apply these agents in undiluted form, as they would kill any plant with which they come in contact, to say nothing of the expense of such a procedure. It is also impossible, as is well known, to mix them with water. However, by first stirring them vigorously with soap, and then adding this soap to water, there is formed what is known as an emulsion. The oil exists in a very finely divided condition throughout the liquid, very much in the same way that small particles of butter-fat are present in newly-drawn milk. In this form the oil is not injurious to the tree, and is sufficiently strong to kill the insect. Great care has to be exercised in applying these emulsions to plants with tender foliage. They are usually applied in the dormant season and if it is necessary to use them on evergreen trees they are diluted to such an extent as to minimize the possibility of injury.

In the case of citrus trees in southern and central California, a very effective method, known as fumigation, has been perfected. In this process trees are covered with canvas tents, and a definite quantity of hydrocyanic acid gas is then introduced into these tents. The gas is very deadly, and the method is exceedingly effective for the control of scale and

insect pests. It is, however, not adapted to the control of those insects which have the ability to move about. Furthermore, because of the deadly nature of the gas, its use is always attended with danger, and should not be undertaken by a person who is not familiar with it. The gas is obtained by treating sodium cyanide with sulfuric acid, when a chemical reaction takes place in which hydrogen cyanide is liberated into the air.

339. Importance of a study of life history.—A complete account of the metamorphosis of any given insect, the conditions under which the changes take place, times of year at which they occur, food on which the insect lives during the



FIG. 116.—The codlin-moth, showing stages in life history. a, egg; b, larva; c, pupa; d, adult. (Greatly magnified.)

different stages and all other matters connected with these changes is known as the life history of the insect. A knowledge of this history is the first essential in devising methods of control, for such a study reveals the insect's weakest point and this suggests the method of attack most likely to result in effectual control.

An interesting case in this connection is that of the codlin-moth (Fig. 116). The larva of this moth leaves the fruit in the fall and spins a cocoon in which it lives during the winter. These cocoons are commonly found underneath loose scales or bark of the trees where the larvæ have been feeding. In the spring of the year, about the time that active growth begins again, these larvæ pupate in the same cocoons in which they spent the winter. After two or three weeks as

pupæ, the adult moths emerge and deposit their eggs on the leaves of the apple or pear and occasionally on the newly formed fruits. The young insects hatch from these eggs, eat into the fruit and remain there in the larval form until fully grown. This requires about three weeks. They then leave the fruit, pupate, and change into the moth stage.

Eggs for the second brood are now laid and the larvæ go through the same cycle as did the first. In those regions where there are only two broods in the year, the larvæ of this second brood live through the winter as already described. In some of the apple-growing sections of the United States, where the season is long, a third brood may develop in the summer or early fall.

In this entire cycle, there is just one vulnerable point. This is the point at which the young larva starts to enter the apple. The egg hatches just about the time the petals drop in the spring. Very soon after that the young larva crawls to the blossom-end of the apple, and there enters through the calyx-tube. It must eat its way in to gain access to the interior of the fruit. This is the point at which it can be caught. A poison spray applied to the apple in such a way as to cover the open calyx end will kill practically all of the young worms. To do this, however, it is necessary that the spray be applied before the calyx-tube closes. If the spraying is delayed too long, it is impossible to get the poison material inside the closed calyx-tube, the insect finds its way between the sepals of the calyx-tube, and thence eats into the apple, without coming in contact with any of the poison. A spray delayed two weeks may, therefore, be entirely ineffectual; but if the material is applied at just the correct time, the number of apples infested with worms will be very small indeed.

340. Control.—The codlin-moth is controlled by spraying with some arsenical poison, the most common of which is arsenate of lead. This material is applied at the strength of three pounds of paste or one and one-half pounds of powdered

arsenate of lead to one hundred gallons of water, just after the blossoms drop and before the calyx-lobes have closed over the end of the little apple.

In cases in which there is a bad infestation in the orchard, more than one spray must be used. Usually two at least are necessary, the second being applied from two to three weeks after the first. Later spraying must be timed by the egg-laying of the moths or the occurrence of the little larvæ just hatched from the eggs. Thoroughness in the application of the spray is the most important factor in successful control.

341. Borers (Figs. 117-118).—Much damage sometimes results to fruit-trees from the attack of borers. Of the



FIG. 117.—Larva of flat-headed borer.

numerous species, the flat-headed borer is the one most commonly seen. East of the Rocky Mountains, a species of beetle known as the round-headed borer occurs commonly.

The flat-headed borer in its mature state is a little dark colored beetle, with metallic reflections. But it is the larval form that is of chief concern. This larva has a small head and a tapering body. Just back of the head is a greatly enlarged segment which looks to the casual observer as if it were a part of the head. Because of this enlarged segment, the insect has the name of the flat-headed borer.



FIG. 118.—Adult of flat-headed borer.

The mature insect deposits its eggs on the bark of the tree. From the egg hatches the larva just described. This larva feeds at first just beneath the bark of the infested tree. Sometimes it completely girdles the tree. After feeding for a time, it begins to burrow into the heart-wood. The burrow is of a characteristic oval shape and thus may be distinguished from that of the round-headed borer which is circular in cross-section.

The adult of the round-headed species is a beautiful

brown beetle with long antennæ and white stripes on the wing-covers. The larvæ somewhat closely resemble those of the flat-headed borers but are more circular in outline. The injury is quite similar. In the case of this species, however, it takes three years for the larvæ to undergo all the different stages of their development and change into the adult.

In addition to these two types, the shot-hole borer is common in fruit-growing regions both of the East and the West. The adult is a tiny brown beetle which lays its eggs in the bark of fruit-trees, where the larvæ hatch and begin to construct their characteristic burrows beneath the surface. Trees which are infested always have small holes resembling shot-holes in the bark. It is from this fact that the name of the insect is derived.

In the case of all these different boring insects, injury is greatest in case of weakened trees. Sun-scalded trunks or branches are nearly always attacked by one or the other of these borers. It is of utmost importance, therefore, that young trees be kept in active vigorous condition, and that the bark of the young tender trunks be protected from the sun. The beetles of the shot-hole species breed in dead wood, either when on the trees or when piled in the orchard, a fact to be remembered in planning the work of control.

Another boring insect commonly seen in the orchard is the termite or, as it is commonly called, the white ant. This is usually a little white, yellowish, or sometimes dark colored insect, resembling an ant. Entrance to the tree is frequently gained through a crown-gall which protrudes above the surface of the ground and where more or less decay is taking place. Like the other borers, the termites rarely attack a quite healthy tree.

342. Apple-tree leaf-roller.—From time to time, the pest known as the apple-tree leaf-roller becomes very troublesome in the orchard, injuring both the fruit and the foliage. The

injury to the fruit consists of scabbing and distortion because of portions eaten away by the larva.

The adult is a little moth having a wing expanse of about five-eighths of an inch to 1 inch. It is rusty brown in color with more or less lighter brown or white markings on the wings. The eggs are laid on the bark of the fruit-trees in the summer. These may be found in little masses of ten to one hundred fifty eggs covered with a protective varnish-like secretion. In shape the clusters are more or less oval or circular, the greater length being about three-sixteenths of an inch and the lesser about one-eighth of an inch.

Hatching is in the spring just after the buds begin to burst open. The period of hatching is somewhat long and larvæ may be emerging from the eggs in the same mass for two weeks or more. Immediately after hatching, the larvæ seek as a feeding place the unfolded buds, which are often injured to the extent that they drop from the trees. The larva spins a web about the leaves in the bud, sometimes preventing unfolding. When fully grown or after feeding for about three weeks, the larvæ pupate, usually on the foliage, changing to the moth stage in about two weeks. The moth then lays eggs, and the life cycle begins again. There is only one brood of the insect during the season.

Control is best accomplished by a very thorough application of miscible oil. This material can be purchased in the market and requires only dilution with water before being applied. This should be done at the rate of one gallon of the spray material to fifteen gallons of water.

343. Canker-worms.—Fruit-trees are frequently attacked by canker-worms, of which there are two species, the spring and the fall canker-worm. The eggs of the spring insect are deposited during the months of March and April, hatching shortly after growth of the trees begins, the larvæ feeding on the foliage. The eggs of the fall species are laid about August or September, the winter season being spent in this

stage. The larvæ are quite variable in color, some of them being green, others brown and still others almost black. They are quite slender and, when full grown, are practically one inch long.

These canker-worm larvæ are very often called measuring worms because of their peculiar looping way of traveling. They have two sets of legs, the forward set being called prolegs. The two species differ in the number of these prolegs; the spring insect has two pair, while the fall species has three.

Control is best brought about by the application of arsenate of lead while the larvæ are quite small. Nicotine-sulfate has also been used successfully, especially at the time when the larvæ are not more than half grown. When they become adult, they may devour large quantities of spray-covered foliage, without being killed.

The female moths of both species are wingless and herein differ markedly from most other moths. Because of this fact, control has been accomplished by the placing of sticky tangle-foot or some other kind of band around the trunks of trees to prevent the female moths from climbing up to deposit their eggs.

344. Red-humped caterpillar.—Frequently fruit-trees are infested by a larva which is characterized by a red head and red hump bearing black spines. This hump is on the first abdominal segment. The abdomen bears stripes which are also quite characteristic of the species. This larva, because of its appearance, is called the red-humped caterpillar.

The adult of the insect is a brown or grayish moth. It lays its eggs on the leaves of the host plant where they hatch, the larvæ afterwards feeding gregariously, that is, in clusters. The winter season is spent in the pupal stage, the moths issuing from the pupa cases in the spring, to deposit their eggs.

Control may be brought about by removing the clusters of

larvæ from the infested trees. This is done by cutting the branch on which they are feeding. Since this insect devours the foliage, a poison spray such as arsenate of lead or paris green can be used effectively in its control. It does not, however, usually become serious enough so that spraying is necessary.

345. Tent-caterpillar.—There are two species of tent-caterpillars. One is commonly known as the eastern apple-tree tent-caterpillar, the other as the western apple-tree tent-caterpillar. The adult moths as well as the other stages of the two insects are very similar in appearance. The brown moths are distinguished by two white bands on the wings. They have a wing expanse of about one and one-half inches or less. The larvæ are covered with a dense mass of hairs. In color, they are black or yellow with white stripes and blue or white dots on the side. In length, the adult larva is about one and three-fourths inches.

The eastern species constructs a large web nest which may be commonly seen in cherry as well as apple trees. The eggs of both species are laid in a mass encircling a small twig of the host plant. The winter season is spent in this stage.

Control of either species may be accomplished by the removal of the infested twigs or by a thorough application of an arsenical spray, preferably arsenate of lead.

346. Fall webworms.—Like the tent-caterpillars, the fall webworms of the East and of the coastal region of the West are different. In each case, the adult moth has snowy white wings with an expanse of about one and one-half inches. The eastern species differs from the western in having a spotted abdomen. The female moth of each deposits from four to five hundred eggs on the leaves of the trees. These leaves serve as food for the larvæ. The larvæ are gregarious in their feeding habits and large colonies may be found in web nests spun about small branches of the tree.

The winter season is spent in the soil or on the trunks of

trees in the pupal stage. Control may be effectively accomplished by the removal of the web nests containing the larvæ, especially in cool weather or at night when all the larvæ are within the nest, or by spraying with arsenate of lead or some other good arsenical spray.

347. Plum curculio (Fig. 119).—A very common and serious pest east of the Rocky Mountains, both of the stone-

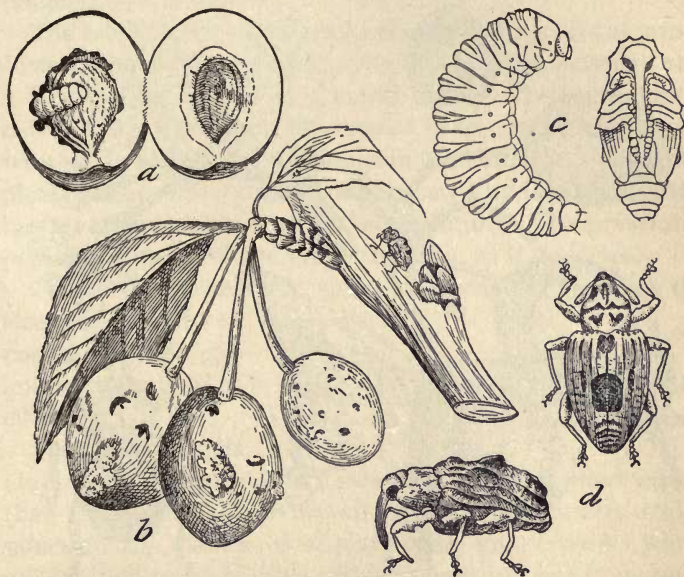


FIG. 119.—The plum curculio. *a*, larva in fruit; *b*, fruit punctured by beetle; *c*, larva and pupa; *d*, adults.

and pome-fruits, is the plum curculio. It does not occur in any of the fruit-growing regions west of the rockies.

The adult is one of the so-called snout beetles. These are distinguished from other Coleoptera by the head being prolonged into a beak which is often as long as the remainder of the body. The beetle punctures the skin of the apple, peach, plum, or other fruit, depositing its eggs just beneath the surface

and forming, wherever an egg is laid, a little crescent-shaped mark. The egg hatches into a little footless larva or grub, whitish in color and about one-third of an inch long. This larva feeds in the fruit until fully grown, when it transforms into the pupal stage, later developing into the adult beetle. The insect hibernates as an adult in rubbish near trees where it feeds. In the early spring when the buds are unfolding, more

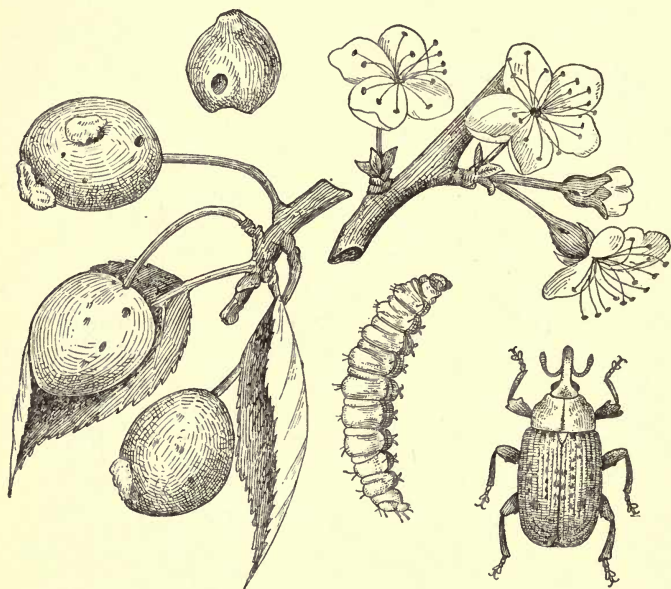


FIG. 120.—The plum gouger and its work, showing injured blossoms and fruits, larva and adult.

or less feeding is done by the beetles on the tender tissues of the leaves. One female lays from one to three hundred eggs.

Control of this pest is best accomplished by means of an arsenical spray which must be used at least three times in the season. The first application for codlin-moth or apple-worm also serves to destroy large numbers of the adult plum curculio beetles. A spray three weeks later, which is also

about the time for second application for the codlin-moth, is valuable in the control of the curculio and a third spray two weeks later should be made if serious injury is feared.

348. Plum gouger (Fig. 120) is another snout beetle, closely resembling the plum curculio. Its native habitat is the wild plum of the Mississippi Valley and Rocky Mountain regions. The injury to the plum is somewhat similar to that inflicted by the curculio.

The adult beetle differs in having no humps on the wing-covers such as those which occur on the plum curculio, and it is also characterized by a longer snout. The beetle hibernates during the winter, coming out in the spring when plum trees are in bloom, and first feeds in the blossoms. The small plums as they are forming are punctured by the snout of the beetle and eggs are laid within the puncture. The larva feeds principally inside of the pit of the plum as it develops.

Control by means of a spray of arsenate of lead at the strength of three pounds to fifty gallons of water may be effective.



FIG. 121.—Scale insects — three mature *Citricola* and one black scale.

349. Scale insects

(Fig. 121).—No pests on trees and shrubs do more injury than the scales. These are all tiny sucking insects which puncture the tissues of a plant with mouth-parts which are adapted to sucking and which pump the sap from within. Two general types are recognized by the entomologists. One is known as the armored scale and the other as the lecanium scale. The former secretes a scale which forms a protective covering separate from the body of the insect under which it lives. The lecanium type of scale is protected by a hard shell which is not separated from its body. San Jose scale is a good example of the armored type. The black scale of California and the hemispherical scale of the East are instances of the lecanium type.

350. San Jose scale.—If the twigs or even the larger limbs and trunks of a tree infested by San Jose scale are examined in the winter, little black or gray scales varying in size from almost microscopic to about one-sixteenth of an inch in diameter may be seen. By raising one of these scales with the point of a knife, the little yellow body of the insect may be discovered underneath.

While there is an egg stage of this insect, the eggs are not laid but hatch within the body, and the young are born alive. At first they have the ability to travel about over the tree by means of six little legs. In a very short time, however, they become attached to foliage, fruit, or twigs by means of their beaks. The legs disappear and the power of locomotion is lost. Throughout the remainder of the life of the female insect, no movement from one place to another occurs. In the case of males, wings are developed which enable them to fly for some little distance.

Control of the armored scales is usually by means of a thorough application of lime-sulfur spray at the strength of 1 gallon of lime-sulfur to 10 gallons of water, or by using some form of oil emulsion spray. In California, where the black scale is a serious pest of citrus trees, fumigation with hydrocyanic acid gas introduced under a tent placed over the tree is the remedy.

Many insects have natural enemies which tend to keep them in check. The eggs of a parasitic insect are shown in Fig. 122, attached to a larva. These eggs will hatch and in the course of time will destroy the host. The predaceous insects, some of which are shown in Fig. 123, devour aphids and scale insects and other forms, and thereby assist greatly in the work of control.

351. Plant-lice (Fig. 124).—There is scarcely a plant that is not attacked by one or more species of little soft-bodied insects called plant-lice or aphids. They derive their nourishment from the plants by sucking it from the tissues through

beak-like mouth-parts. Some of the worst pests of orchards belong to this group. Plants that are attacked by the aphids are very often covered with ants, the reason being that ants are very fond of the honey-dew which the plant-lice excrete. Ants have been known to care for certain species of aphids during the winter, taking them into their nests and placing them on their host plants in the spring.

The method of reproduction among this group of insects is unusual and interesting. Many of them



FIG. 122.—A parasitized larva.

spend the winter in the egg stage. In other seasons of the year there is no egg stage and reproduction takes place viviparously; that is, living young are produced without any egg stage. Generation after generation of these lice are produced on plants during the active growing season and some species continue feeding throughout the winter months.

The life history of the common woolly aphid of the apple is characteristic of the members of the entire group and is as follows: During the summer time, twigs, foliage, and roots of apple trees may be

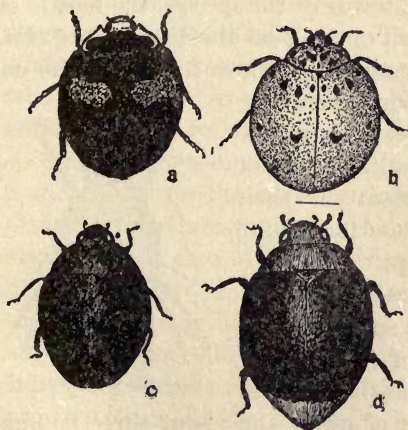


FIG. 123.—*a*, The Eyed Ladybird and *b*, Ash-Gray Ladybird, predaceous on aphids; *c*, the Black Ladybird predaceous on black scale; *d*, the Mealy Bug destroyer.

abundantly infested with this little woolly coated insect which feeds by means of a beak inserted into the leaf or the

twig. When feeding first begins in the spring of the year, it will be noticed that all the lice are wingless. This is also true throughout the summer. Early in the fall, however, a generation develops wings and has the ability to fly from one tree or one plant to another.

For years it was not known where these winged lice went

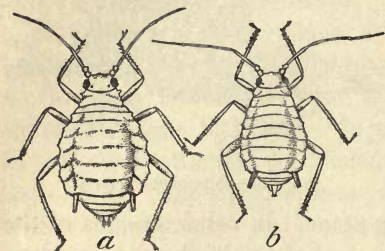


FIG. 124.—Aphids or plant-lice.

after flying away from the apple. It was finally discovered by Edith M. Patch, entomologist of the state of Maine, that the elm tree serves as an intermediate host for this pest. When the lice developed wings, they flew from the apple to the elm and there pro-

duced viviparously sexual forms of the species, the female of which was found to deposit one egg on the bark of the elm. There hatched from this egg a louse which fed for a time on the elm, but the succeeding generation, attaining wings, migrated back to the apple. All species of plant-lice do not follow this peculiar custom in their migration, but nevertheless it is quite characteristic of the group.

Control of all species can be accomplished by very thorough spraying with nicotine sulfate (Black leaf 40) and soap, using the nicotine sulfate at the strength of one part to 1000 parts of water and about three pounds of whale oil soap to two hundred gallons of the diluted spray. Thoroughness in the application of the liquid is exceedingly important.

Nicotine sulfate is a poison which must come in actual contact with the insect before it will kill; therefore, in the

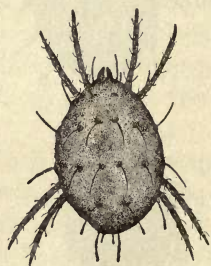


FIG. 125.—Red-spider.

work of spraying for the control of any of the plant-lice, the greatest care must be exercised in order that practically all of the lice receive an application of the spray.

352. Mites.—Under the term “mites” is included a number of the so-called red-spiders (Fig. 125). These often do considerable injury to the foliage of fruit-trees and other plants. Three species are common. These are known as the brown or clover or almond mite, the two-spotted mite, and the citrus mite. Of the three species, the two most commonly seen are the brown and the two-spotted mite. The former may be found during the winter season in the egg stage, the eggs being deposited about the buds or in the crotches of deciduous fruit-trees. They are tiny red objects of a glassy appearance which remain unhatched until warm weather comes in the spring. As soon as the buds begin to unfold, the tiny red mites hatch from the eggs and begin to feed.

The citrus red-spider also spends the winter in the egg stage on deciduous fruit-trees. There might be more or less confusion as to which species was present, in the mind of one who is untrained in entomology, but the eggs may be differentiated by the following character: In the case of the citrus species, the egg is more or less flattened at the poles and bears a short stem on the upper surface to which are sometimes attached fine threads that anchor it to the leaf. These are absent in the case of the spherical shaped brown mite egg. The two-spotted mites differ from the other two species in their hibernating habits, as they may be found during the winter in the soil about fruit-trees. The early injury to fruit-trees which takes place is almost sure to be that of the brown mite, while about midsummer, June or July, when the weather becomes hot, the two-spotted mite frequently becomes very abundant.

This two-spotted mite is a web-spinning form and, wherever prevalent, the foliage of infested trees is covered with a fine gauze. There is no web present when brown mite is the

attacking species. The citrus red-spider is also a web-spinner and is found commonly on citrus trees, but occurs as well on pears, apples, peaches, and certain other kinds of deciduous fruit-trees.

During the summer time, the eggs of both the citrus red-spider and the two-spotted mite may be found on the surface of infested foliage. The eggs of the former are red in color as are also those of the brown mites, while the eggs of the two-spotted mite are white and appear as little pearl-like objects, very inconspicuous on the surface of the leaf.

353. Control of mites.—In the case of brown mite and citrus red-spider, each of which spends the winter in the egg stage, control may be effected by treating thoroughly with lime-sulfur at the strength of one gallon of the liquid to ten gallons of water in the early spring as the buds are swelling on the deciduous fruit-trees. In the case of the two-spotted mite, which does not spend the winter season in the egg stage, this treatment would be of no avail. As a substitute for lime-sulfur, any of the oil emulsions may be used, application being made at the same time as with the former.

During the summer, when active feeding is taking place, control may be effected by an application of sulfur in some form. Atomic sulfur is now very commonly and very successfully used in red-spider control. Since all species are killed by sulfur, this may be considered the standard remedy.

354. Blister-mites.—In addition to the so-called red-spiders, a group known as blister-mites affect some fruit-trees. The most common species, one which is distributed widely through the different states of the Union, is the pear-leaf blister-mite.

This little pest winters beneath the scales of pear buds, crawling out when the buds begin to unfold in the spring, and begins to feed just as soon as growth appears. There is a characteristic reddish-colored blister-like patch which forms wherever this mite attacks the foliage. Feeding takes place

within the tissues of the leaf and injury is sometimes severe. This injury is not confined to the foliage but also extends to the fruit, causing scabbing and more or less distortion.

The control of this species is best accomplished by a thorough application of lime-sulfur as recommended for the brown mite and citrus red-spider. Treatment should be given just as the buds begin to swell in the spring.

In addition to the pear blister-mite, several other species are of economic importance. Two in particular should be mentioned, the life histories of which are similar to that of the pear-leaf blister-mite. These are the walnut blister-mite which attacks both English and black walnuts, and the grape-vine blister-mite which causes a condition commonly known as erinose of the vine. The same treatment that is necessary for the pear-mite will control these two species.

Another species not commonly seen and by far the smallest mite known, is the pear-leaf rust-mite, which commonly attacks the foliage of the pear and which is recognized by a rusty appearance of the infested leaves. Treatment with sulfur in any form is all that is necessary to control this species.

355. Opportunities for insect study.—Students frequently have the idea that study must be confined to books. Nothing could be further from the truth. Books help, most certainly, but they never can take the place of observation at first hand. In insects the student has a most fertile field for observation and study. He will find everywhere an abundance of material. He will be able to determine for himself such matters as feeding habits, life histories, and economic control. He should get assistance from books on insects, from his instructor and from experts in entomology. But it will not be very long, if he observes closely, before he will begin to discover facts that no one else has noted. He will, in his own small field, be ahead of the text-books. He will be among those who are adding to the sum total of human knowledge. The

facts set down in this chapter are brief summaries, dealing with a few insect groups, but there are thousands on thousands of different species, many of which are an economic menace to the horticulturist and all of which furnish fruitful material for study.

EXERCISES

EXERCISE I.—Study of the codlin-moth.

Materials.—"Wormy" apples or pears; knife; a few collecting bottles or small vials partially filled with 3 to 5 per cent solution of formalin.

Procedure.—Remove the codlin-moth larva from the apples or pears by cutting them first into halves. Make careful drawings of the burrows of the larva in the fruit. Draw a larva. Describe the appearance, including the size, color, and shape. Notice the entrance hole through the side or end of the fruit, and the mass of frass around the core. Read as many references on the codlin-moth as possible. Include in your notes facts relating to its distribution, a list of the kinds of fruits attacked by it, and an account of the best methods of control.

EXERCISE II.—Study of apple-tree borer.

Materials.—Sharp knife; trees infested with borers; vials filled with 3 to 5 per cent solution of formalin.

Procedure.—(1) Examine trees infested with the borers. Notice the excrement or castings at the base of the trees infested with borers and the discoloration of the bark above the burrows. (2) With the knife cut out some of the borers and preserve them in the vials containing formalin. Make drawings of the borer and describe it briefly. Read as many references as possible on the borer. Include in your notes the life history, habits, and control measures for the borer.

EXERCISE III.—Study of red-humped caterpillar, tomato-worm, or other larvæ.

Materials.—Small bottles containing 3 to 5 per cent formalin solution; infested plants or trees.

Procedure.—Study the type and extent of the injury done by the larva. Note its mouth-parts. Preserve some of the larvæ. Write a complete account of the nature of the work of the insect, its life history, distribution, food plants, and control measures.

EXERCISE IV.—Study other insects common in your locality, following the above methods.

Make studies of the egg, larva, pupa, and adult stages wherever possible.

EXERCISE V.—Study of insecticides.

Materials.—As many insecticides as possible; glass jars or glass cylinders; water.

Procedure.—Study each material as to the following: Form, whether solid or liquid; color, fineness, solubility in water, precipitation.

EXERCISE VI.—Test for inert material in paris green.

Materials.—Samples of paris green, strong ammonia, test-tubes.

Procedure.—Dissolve a small amount of paris green in a test-tube half filled with strong ammonia. The paris green dissolves but inert material remains in the form of a precipitate.

CHAPTER XVII

PLANT DISEASES

PLANT pathology is a comparatively new science. It is only within recent years that it has been recognized that plants are subject to diseases just as are animals, and that these diseases in turn are proper topics for scientific study. It has been vaguely recognized for a long time that certain factors have retarded the activity of the plant, causing loss of crops and in many cases entire destruction to the plants involved. A scientific study of the phenomena was not undertaken, however, until well along toward the close of the nineteenth century. At present, every well organized college of agriculture has a department of plant pathology; and research in this field is adding immensely to man's knowledge of the subject and consequently to his power of control.

356. Causes of plant diseases.—The cause of most plant diseases is some invading organism belonging to the lower forms of life, that is, to the bacteria and other fungi. It may be said in passing, that a fungus is itself a plant that possesses no green coloring matter. On that account, it cannot manufacture its own food and it lacks in structure many of the characteristics of the higher plants. Organisms of this sort invade the tissue of the higher forms, sapping the nourishment from them, and deranging their functions in such ways as to produce symptoms of disease.

357. Fungi.—As already stated, fungi are plants; they are not like those with which we are acquainted, in that they are very much simpler in their structure. They have no roots, stem, leaves, flowers, or seeds, as these terms are defined in

the higher plants. They consist of thread-like filaments which may occur singly or in tangled masses, or organized into more or less definite forms. The fungi have many different degrees of complexity, from the exceedingly simple bacteria, consisting of only one cell with its contents, to the very complicated mushroom with its thousands of cells and intricate structure. But even the complexity of structure in the mushroom does not compare with the differentiation of tissues in the simplest of the flowering plants. These fungi have no flowers and produce no seeds in the botanical sense. Instead, they have reproductive bodies called spores, which are usually exceedingly small, and are easily distributed from place to place. Some idea of their prevalence may be gained from the fact that ordinary bread placed under conditions of warmth and moisture will invariably develop bread mold; and this mold is merely one among thousands of similar fungi.

358. How fungi grow.—Every green leaf contains thousands of very minute green particles called chlorophyll bodies. These are the active workers which enable these plants to change the crude sap received from the ground into manufactured food such as starch, sugars, fats, and oils.¹ Fungi, however, possess no chlorophyll; and since they, like all other plants, must have these manufactured foods, it follows that they can live only on the food manufactured by the higher organisms. All fungi are, therefore, either parasites or saprophytes; that is, they live either on living plants or animals, or on dead material. It is the former class that is especially active in producing plant diseases.

The spores (Fig. 126) of the fungus are carried in one way or another to the surface of the leaf or stem. If conditions are correct (in general, if the air is warm and humid), these spores germinate and penetrate the surface tissue of the plant. The new fungi then grow down through the cells of the host

¹ See Chapter II.

extracting nourishment and rendering them useless. As this process goes on, the fungus gradually gains in size and strength, and spreads rapidly in all directions to the unaffected portions of the plant tissue. After a certain stage is reached, the fungus puts forth a new type of growth which, in most cases, extends outward through the epidermal cells of the plant into the air. On the ends of this new growth, sacs form containing spores. These are soon scattered to



FIG. 126.—A fungus showing spores.

other leaves or plants and the process begins all over again. Since in many cases the spore-sacs produce hundreds and even thousands of spores, and since each fungus bears many such sacs, it is easy to understand that the disease will spread very rapidly unless checked.

359. Control.—It is clear that the fungus must be controlled before it gains access to the tissues of the plant. This is accomplished in a number of different ways. If the spores are carried to the fields by the seed, the natural method is that of seed disinfection. The material commonly used for the purpose is a solution of formalin or of corrosive sublimate. Spores gain access commonly through wounds in the plant.

It is obvious that every care must be taken to avoid injury and thus reduce the possibility of infection to a minimum. Very frequently decay is caused in fruit by careless handling, which bruises the skin and provides means of access for the spores. In view of these facts, the method of fruit handling becomes of the utmost commercial importance.

The fungicide most commonly employed is some form of sulfur. This may be put on the plant either in the dry state or it may be applied in the form of a spray, the most common materials used being lime sulfur and bordeaux mixture.

360. Bacteria are very minute organisms exceedingly

simple in structure, consisting of a single cell only. They are almost universally present. If one should wipe one's finger across the desk there will be literally thousands of bacteria on the finger tip. A glass of ordinary milk, even if the purest certified, will probably contain more than a hundred thousand bacteria. If the milk has not been handled with great care, this number may be counted in the hundreds of millions. The earth swarms with bacteria, many of which are beneficial to plant life. But, on the other hand, many are injurious and the total injury by them yearly is enormous.

Reproduction takes place with such rapidity that a single bacterium may in the course of a day or two increase under favorable conditions to many millions of individuals. If climatic or other factors are unfavorable, they have the power to form hard crusts about themselves and in this state may remain quiescent for months or even years, ready to grow and multiply whenever the environment is favorable.

Bacteria multiply by a process of simple division. One bacterium divides into two, these into four, then eight, sixteen and so on. If such division takes place every hour (as is sometimes the case, when food and temperature factors are favorable) it is a matter of simple arithmetical computation to ascertain the number to which one bacterium would increase in, say, twenty-four hours.¹

Some bacteria are motile, that is, they have propelling organs by means of which they are able to move through a limited space. Others have no such structures. All bacteria thrive best under conditions of warmth and moisture, coupled with abundance of food material.

361. Pear-blight (Fig. 127) is one of the diseases known to be directly due to bacteria. They gain access usually either through the flowers or through the tender growing parts of the plant, and then spread, attacking the cambium layer just beneath the bark. This cambium is the actively growing

¹ It is suggested that the student make the computation.

portion of the plant, and here the bacteria that produce the disease grow and multiply with amazing rapidity. From the tips of the branches they spread downward, killing the limb as they advance. The leaves are

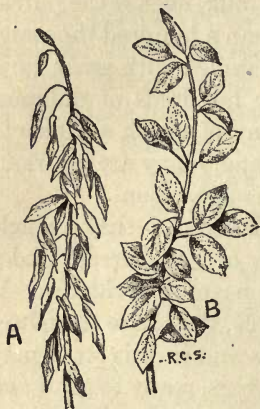


FIG. 127.—Pear-blight. A, diseased twig; B, healthy twig.

left without nourishment and very soon wilt and die, making the limb appear as if it had been injured by too much heat. On this account, the disease is sometimes called fire-blight. If the bacteria gain access through a small branch which grows on one of the larger limbs, the disease may entirely encircle and kill it; or if they gain access through suckers that grow at the base of the tree, they may kill the entire tree in a similar way in a very short time.

It has been demonstrated that insects flying from flower to flower are chiefly instrumental in spreading the disease. Bees are probably the chief agencies in this respect. These come in contact with the disease on one plant or part and then carry the bacteria with them when they fly to other unaffected portions.

A limb or other part of the tree that has been attacked cannot be cured. The bacteria are located under the bark where they cannot be reached by any spray and are not subject to surface control. It has been necessary, therefore, to devise other means of treatment, such as amputation of the diseased parts. Wherever wilting appears, indicating the presence of disease, the limb should be cut off immediately. To avoid any possible infection, the scissors or pruning-shears with which the cut has been made should then be dipped in corrosive sublimate¹ solution prepared one to one thousand. The wound should be disinfected with a solution



Plate VII.—Upper: A thrifty vineyard with orchard in background.
Lower: Strawberries grown in matted rows in young apple orchard.

of cyanide of mercury¹ at a strength of one gram to five hundred cubic centimeters of water. Corrosive sublimate is not the best disinfectant for wounds, and the other does not work well as a disinfectant for tools.

The limb which has been cut off must be burned at once. In this way the disease can be definitely kept in check, but in those regions where it is well established, eternal vigilance is the price which each pear-grower must pay if he hopes to keep his orchard. Sometimes the disease can be detected in winter through the shriveling of the bark, but this calls for expert observation and for the amateur the surest way is to wait until the leaves appear in spring, when the progress of the disease can be definitely noted.

Considerable thought is being given to resistant stocks. Some varieties of Chinese pears are not susceptible to blight and these are being used. Such a method does not save the tops from being attacked, but it does insure that the root will not be killed by the disease.

362. Powdery mildew, found chiefly on the grape, has been known for three-fourths of a century and is a constant problem to grape-growers not only in the United States but throughout Europe.

It can be seen readily on the leaves of diseased vines, occurring on both the upper and lower surface as whitish blotches, more or less rounded in shape. It does not confine itself to the leaf, however, but attacks all parts except the root. Blossoms which are mildewed do not set their fruit, and fruit itself, if it be affected, soon ceases growth and falls, or develops irregularly and fails to ripen.²

Thousands of tons of sulfur are used every year in the grape-growing sections of the United States in the control of this disease. This sulfur is carried on the back of the

¹ Both substances are very poisonous! Young children should never handle either.

² Stevens and Hall: *Diseases of Economic Plants*.

operator in a sort of knapsack, which connects with a bellows. The operator works the bellows as he walks along the row, giving each vine a thorough dusting. A power-sprayer for the purpose is now coming into use. Two applications, sometimes three, are necessary to control the disease. The fungi grow most readily when warmth and moisture are present. Clear cool weather acts as a check and reduces the number of applications of sulfur necessary.

Mildew affects many other plants beside the grape. It is found frequently on rose bushes, and appears also to some extent on peaches, apples, currants, garden beans, and others. In addition to the measures named above, plants should usually be placed in positions where they receive fairly constant sunlight, for this assists materially in keeping down the disease.



FIG. 128.—Crown-gall.

363. Crown-gall (Fig. 128) is a very common disease of deciduous trees. As the name indicates, it affects the crown of the root, just below the surface of the ground. It is a bacterial disease. When the bacteria gain access to the root of the plant, they cause enlargement of the diseased tissue, producing a gall-like appearance. This gall may first be located on one side of the root only, but as the disease progresses it gradually spreads around the root, until the entire crown is affected. As soon

as this occurs, a circle of the cambium layer is killed, connection with the root is severed, and the tree dies. From the time the disease first appears, several years usually pass before it kills the tree.

No cure is known. When the infestation is light, it is sometimes recommended to cut away the diseased portion, and paint with some antiseptic to stop the spread of the disease. In general, however, this is not practicable. It is always necessary, when buying young fruit-trees, to watch the roots

very carefully indeed, since this disease usually makes its appearance in the first place in the nursery. If nursery stock is secured that is absolutely free from crown-gall, the chances of development later in the orchard are very much lessened. Every precaution must be taken to see that roots are not injured in the process of cultivation or in other ways. As before pointed out, the disease is transmissible and it finds ready access through wounds, especially if these are close to the surface of the ground. There is a possibility that a root may be found which will be immune to this disease.

364. Potato scab (Fig. 129).—This common disease of the potato, occurring in all parts of the country, causes an immense amount of damage. It is readily recognized, for it covers the tuber with rough brown blotches as shown in Fig. 129. The outer tissue is destroyed and the tuber becomes unsightly in appearance.

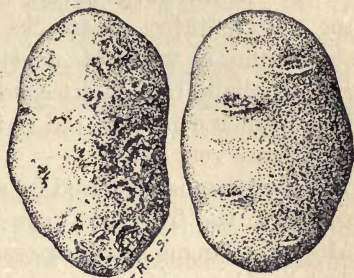


FIG. 129.—Potato scab.

The disease is produced by a fungus which gains access from the seed or from the soil. Since it lives in the ground from year to year, fields in which it has appeared should not be planted to potatoes or root-crops for four or five seasons after it was last detected. There is no other way known at present whereby it can be eradicated from the soil after it has once gained access.

The common treatment to prevent infection from seed potatoes is by soaking in formaldehyde solution. Of course, potatoes which are in the least scabby or which are known to have come from a field where scab has been present, should not be used for seed. It is not possible, however, in the larger number of cases, to ascertain the facts with regard to

seed potatoes, and the precaution should be taken of treating all seed.

The method is as follows: Dissolve a fluid ounce of formalin in two gallons of water, and soak potatoes in the solution for at least an hour. The seed may then be used at once, or dried off and used as desired. If a large amount of seed is to be treated, the solution should be prepared by the barrel, but the proportions given above are maintained.

365. Brown-rot is a very common disease in all parts of the United States. It attacks the peach especially and other stone-fruits as well. Its development is favored by warmth and especially by a moist condition of the atmosphere. The losses which can be traced to it are always considerable and sometimes very heavy.

The disease is produced by a species of fungus which gains access to the fruit and grows there, destroying the tissue. After the fungus has progressed sufficiently, the fruit turns dark in color and begins to shrivel. This is the first indication of the progress of the disease. From the fruit, the fungus may enter the limbs, but, as a rule, the woody parts of the plant are not very susceptible.

Frequently fruit which has become infected with the disease is allowed to hang on the trees and forms a prolific source of trouble during the following year. Spores are present in great numbers in these dried-up fruits and are easily carried to the new ones. Access is facilitated if the fruit is bruised, but the disease also gains entrance even where the skin is whole and healthy. The first precaution in the treatment of the disease is, therefore, to see that all of the affected fruit of the previous year is taken off the trees and either carried off and burned or plowed under deeply enough so that the spores do not come to the surface of the ground.

The next step in control is the use of bordeaux mixture during the late dormant season of a strength of approximately 6-6-50. It is impossible, however, to reach all of the spores

with the bordeaux and, while commercial results can be secured, entire eradication is practically out of the question.

There is a disease of lemons which is also called brown-rot, but this is caused by a different fungus. As the name indicates, the lemon turns brown after the disease has penetrated the interior of the fruit. It is necessary in treatment to spray the ground thoroughly with bordeaux mixture, especially in the vicinity of the trees, for rain splashing the ground may carry the spores to the fruit on the lower part of the tree. The prevalence of this fungus is one of the factors which make careful handling so necessary, for wherever a slight bruise occurs, the spores are able to gain access to the interior of the fruit and decay quickly follows.

The same fungus which causes the brown-rot of the fruit is also responsible for a gum disease of the bark, which has proved serious. This is now kept under control by budding the lemon on such resistant forms as Florida sour stock and by keeping the bud union well above the ground. When the disease appears, it may be checked by scraping off the injured bark and then painting the affected parts with a mixture of blue-stone and lime. One pound of blue-stone and two pounds of lime are dissolved separately in three quarts of water and the two solutions are then mixed.

366. Shot-hole fungus (Fig. 130) produces a disease in which small round discolorations or holes appear on the leaves and fruit. The manner in which these are scattered suggests the effect of a charge of shot from a shot-gun. A number of different species are responsible for the disease. Like all other fungi, these must be treated before they gain



FIG. 130.—Shot-hole fungus.

access to the plant if injury is to be prevented. The sprays most commonly used are bordeaux and lime-sulfur, applied in the early spring.

367. Anthracnose occurs on a large number of plants. On the bean it produces dark markings and blotches on the pods, stems, and leaves. These blotches gradually spread until they produce large irregularly shaped markings. The raspberry and other berries are frequently affected, the disease appearing as purplish spots which gradually become larger and sunken in the center. A form similar to that on the raspberry has done an immense amount of damage to the grape. Legumes other than the bean are also affected by the disease and a large number of other plants are not immune.

Spraying does not suffice in the control of the disease. The affected parts should be removed and burned, and care should be taken that only healthy plants are set out. Since the spores are apparently carried by seed, especially of beans, that source of infection must not be overlooked. When the disease appears, a rotation of crops is desirable that will use for four or five years such vegetables and other plants as are immune to the attacks of the organism.

368. Root-rot.—A number of diseases are grouped under the general name of root-rot. These are produced by several different fungi, called as a class *Rhizoctonia*. As these diseases progress, the smaller roots, or indeed the whole root system, may be killed, although the observer has no knowledge of what is happening until the top withers or even dies. These diseases are especially prevalent on heavy soils, or when the drainage and aeration are not good. A thorough cultivation of the soil, together with proper drainage, is the easiest and cheapest way to protect the roots. Various plants have been reported as subject to these diseases, among which are alfalfa, the orange, cotton, and the grape. Among the vegetables, the bean, pea, potato, tomato, beet, radish, and certain others are susceptible.

Bitter-rot (Fig. 131) is an example of a disease which occurs on the fruit in one form, and on the wood in another. This fungus, when it gains access to the wood, causes a disease known as bitter-rot canker.



FIG. 131.—Apple bitter-rot.

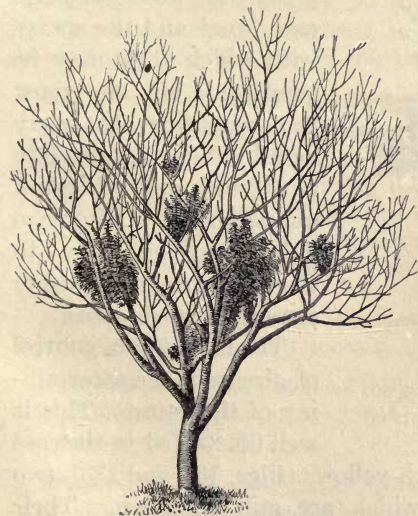


FIG. 132.—Peach-yellows.

369. Damping-off gives considerable trouble especially in the hotbed. The young seedlings wither and fall over and an examination reveals that the stem has collapsed near the point where it emerges from the ground. The disease spreads rapidly, and frequently a large number of plants are affected before it is discovered. The conditions which especially favor its development are moisture and warmth.

As the seedlings crowd up out of the ground and as the leaves develop above, there is a space between the ground and the leaves where moisture does not have a chance to evaporate and this makes an ideal condition for the development of fungus. When the hotbed is kept too warm, a large number of plants may be lost in this way. Care must

be exercised also to prevent moisture from standing on the seedlings any longer than necessary. It is generally desirable to water greenhouses and hotbeds in the morning rather than at night, for the sunlight will dry off the plants and drive the moisture from the stem. If moisture is allowed to remain on the plants over night, they are much more susceptible to the damping-off disease.

370. Control of diseases.—The control of plant diseases is intimately connected with the whole subject of care in all its aspects. The cultivation of the ground, the application of irrigation water, the methods of pruning, and the disposal of prunings and other rubbish, all have a direct influence on

disease control. The orchardist or gardener must not only know a great deal about bacteria and fungi and the sprays with which they may be combated, but also must pay attention to every detail which enters into the business of good management. Only by so doing can he hope to wage a successful warfare against plant diseases.

The first step in control of disease is the ascertaining of the cause. This is well illustrated in the case



FIG. 133.—Peach-rosette.

of peach-rosette and peach-yellows (Figs. 132 and 133), two diseases the causes of which are still unknown. Their control is very difficult on that account.

EXERCISES

EXERCISE I.—Crown-gall.

Material.—Potted geranium plant with actively growing stems. Secure specimens in the locality of crown-gall injury. (This will be found on almost all of the deciduous fruit-trees, especially the peach.)

Procedure.—Note with regard to crown-gall the following points: The general appearance of the diseased portion, its location with regard to the surface of the ground, its effect on the living tissue of the plant, the apparent depth of penetration into the interior of the plant, the appearance of the center of the diseased portion as compared with its outer edges and general appearance of the plant on which the crown-gall is found.

Transmit the disease from the affected plant to a healthy young shoot of geranium in the following manner: Insert the point of a knife blade into tissue affected with crown-gall and then insert the blade into the young stem of the geranium.

Each student should make this inoculation, some using the center of the crown-gall tissue and others the outer edge. The geranium stems thus inoculated should be watched carefully from day to day. The effect of the inoculation will probably begin to appear within a month.

EXERCISE II.—Diseases affecting projects.

Materials.—Diseased portions of plants from students' projects.

Procedure.—Make a study of the diseased plants either in the laboratory or in the field. Identify the disease by referring either to Chapter XVII, to books of reference on plant diseases, to bulletins published by the experiment stations, or in the event that the identification is still uncertain, by direct correspondence with your state experiment station.

Write up a full account of the disease including the cause, nature of injury, control, and all other material of interest.

EXERCISE III.—Study some of the common fungicides in the same way as suggested for the study of insecticides in the exercises following the chapter on "Insects."

EXERCISE IV.—Making various spray mixtures.

Materials.—Various materials for making spray mixtures, utensils for making, and the like.

Procedure.—Make spray materials such as bordeaux solution and lime sulfur.

CHAPTER XVIII

MARKET PREPARATION, TRANSPORTATION, AND STORAGE

IN the moving of fruits and vegetables from the place where they are grown to the market, and thence to the consumer, three stages are involved:

(1) *The market preparation stage* includes such operations as picking or otherwise harvesting the crop, hauling, cleaning, grading, sizing, drying and curing, packing, and loading on the cars; in short all the operations necessary to gather the commodity and place it in proper condition for shipment and sale.

(2) *The transportation stage* includes the loading and routing of cars, and such other operations as are necessary to the safe arrival of the product at the market. If the shipment takes place in refrigerator-cars, as is the common practice with car-lots, the cars are iced and sealed. The commodity is then hurried to its destination by fast freight. Sometimes fruit is kept in cold storage for a time before it is sent to the market.

(3) *Marketing and selling stage.*—In this stage are included all operations pertaining to the actual sale or disposal of the crop. Among them are distribution, handling in markets, advertising, and systems of selling.

Producers are becoming increasingly appreciative of the fact that the operations of these different stages are best performed by specialists who are able to give their entire time each to a particular phase. It happens that in the past most attention has been paid to the processes of production. It is

natural that this should have been so, for it is with production that the grower is most intimately concerned and the problems come home to him by personal contact. Only in comparatively recent years has attention been directed toward a study of the fundamentals involved in marketing, problems just as vital to the success of the fruit and vegetable industry as are those of production.

It was not many years ago that fruit and vegetables were grown only as secondary crops and marketed in towns and cities adjacent to the farms. Now they are raised on a large scale and some of the most perishable products are marketed even thousands of miles distant from the point where they are produced. It is, therefore, necessary, in this age of commercial production, that each step of the process from the growing of the product to its final sale to the consumer should be thoroughly understood by the growers themselves. In the pages which follow the problems of marketing will be discussed with reference to fruits alone; but it must be kept in mind that what is said applies to vegetables as well, though on a smaller scale.

371. Growing and marketing.—There is vital connection between the conditions in the orchard or field and that of the product when it is finally placed on the market. Poor care in the form of inadequate cultivation or fertilization reacts on the quality of the product. Improper pruning of trees results in fruit of poor size or so marred by scratches that it cannot be sold as a first-class product. Insufficient or too much moisture affect the final flavor of the fruit unfavorably. A season during which weather conditions are unfavorable frequently produces a large proportion of fruit of poor quality or appearance.

372. The ripening process.—The fruit is a storehouse of food for the potential plant in the seed. This food is manufactured for the most part in the leaves where it may be found in the form of starch. Later, it is changed from starch to

soluble substances which are transported through the tissues to the fruit. As the fruit ripens, the starch is gradually changed into new material, mostly sugar and fiber; but in addition to these dozens of other substances, such as oils and acids, give to each variety its peculiar flavor. In most ripe fruits the starch which formerly was present in the green fruit has practically all disappeared, and other substances have been formed from it.¹

Change does not stop there. Very soon decay begins, and the fruit becomes worthless for human use. In fact, the tearing down process starts before the building up is completed, and the two go on for a considerable time side by side. At last the process of decay predominates, and the product becomes useless as human food.

373. The time for harvesting.—Time of picking and subsequent treatment will vary, depending on the use to which the fruit is to be put. If intended for a nearby market, it will ordinarily remain on the trees longer than if the market is at a distance. If intended for drying or canning, it will be handled differently than if sold as fresh fruit. If it is to be placed in cold storage, again certain factors of successful practice must be kept in mind. Harvesting, therefore, calls for a constant exercise of judgment on the part of the horticulturist.

It is customary to judge the ripeness of most fruits by their color and general appearance. The quality of the fruit put on the market is subject, however, to increasingly rigid standards. This has led to the adoption of scientific tests for ripeness in the case of certain fruits of whose condition it is difficult to judge.

With grapes, bunches are secured from sections of the vineyard and from different places on the vines so that the sample may be representative of all the fruit. The juice is then

¹ One of the few exceptions to this rule is the banana, the ripe fruit of which contains a considerable proportion of starch.

extracted by placing the grapes in a muslin bag and squeezing the mass with the fingers. The liquid is poured into a glass cylinder into which an instrument called a Balling saccharimeter is introduced. It is necessary to have enough grape juice to float the saccharimeter. The instrument records the percentage of sugar in the juice; for example, if 25 per cent of the weight of the solution is sugar, the reading is 25. The amount of sugar does not need to be so high for table as for raisin grapes. The fruit is suitable for table use when it contains 16 or 17 per cent of sugar. It is not suitable for raisins until this percentage has risen to 24 or 25 or higher.

With oranges also there is a standard test for ripeness. In this case two factors must be taken into account. The first is the percentage of solids (principally sugar) dissolved in the juice of the fruit. The second is the percentage of acid in the juice. The standard depends on the ratio between these two percentages. An orange is considered ripe according to this test when there are eight parts of soluble solids in the juice to one part of acid. This is the so-called 8 to 1 test. It is probable that in the future tests will be devised for many other fruits. Experiments in this field are being conducted at the present time.

374. Decay.—Each year large losses of fruit occur due to decay in transit. This is not merely the natural and unavoidable decay caused by over-ripeness, but represents largely an unnecessary loss resulting from careless handling. Molds of several kinds, the most common of which is blue-mold or mildew, attack and destroy the fruit. It has been demonstrated that, as long as the skin remains unbroken, the mold cannot gain entrance, but the slightest injury, such as a scratch from the branch of a tree, a bruise in handling, or an abrasion from the finger-nails of the packer or picker, is sufficient to allow the fungus to gain access to the fruit. Once the tissue has been invaded, the entire

fruit is quickly destroyed. The problem of the grower is to see that in each stage of the handling the skin of the fruit is kept whole.

375. Picking.—The precautions will differ with the various fruits. Raspberries and other berries are injured by holding too many in the hand while picking. Even a matter seemingly so trivial as the use of two fingers instead of three in picking raspberries may have considerable influence on the keeping quality of the fruit. Oranges and lemons are not pulled or broken from the stem, but are cut with clippers which have curved edges. In using these, care must be exercised to see that the clippers do not injure the fruit, and at the same time that the stem left is not long enough to puncture any other orange which may come in contact with it. It is a common practice in the case of the softer fruits to squeeze them gently when picking to ascertain their ripeness. This is injurious and invariably results in a considerable proportion of decayed fruit. Even if the product is to be utilized immediately in the cannery or drying yard, injuries of this sort should be carefully avoided.

When in field-boxes or other containers, fruit must not be heaped up so that one box will cause injury to the fruit in the one below. Fruit must be laid in the picking-boxes and not thrown or handled in other rough ways. Gravel and sand or twigs in the picking-boxes are sources of trouble as are also splinters or nails. The old rule is that fruit must be handled like eggs; but this is rather an under-statement as, in many cases, it must be treated very much more carefully than eggs.

376. Hauling.—Care is essential also in hauling. The wagon or other vehicle should be provided with springs to lessen the damage by bruising. One of the best investments which a fruit-growing district can make is for good roads; for these reduce to a minimum the amount of injury to the fruit between the orchard and the packing-house.

PACKING-HOUSE OPERATIONS

The packing-house performs today efficiently the operations which twenty-five years ago were attempted in a desultory way on the farm. The fruit is sometimes brushed or polished and in some cases washed. These processes increase the chances for injury and consequent decay and have to be performed with the greatest care. Grading the fruit consists in sorting according to color, quality, and size. The grading may be done either by hand or by machinery. Its purpose is to enable the packer to put the fruit up in such a way that each container is filled with a fairly uniform quality and size.

377. Packing.—Systematic packing is advantageous to the industry in several ways. It results in a more attractive product; and this always reacts to create a better market. It adds to the carrying quality of the fruit, for in good packing the contents are placed in the package tightly with no chance to move about. It facilitates shipment and delivery to the wholesaler or retailer. It enables a grower, an association, or a community to build up through a period of years a reputation for a good product so that the name on the outside of the package carries a guarantee of the quality of the goods within.

Just as in the processes of picking, hauling, and grading, great care is necessary in packing. There is a possibility of injury from finger-nail scratches, from throwing the fruit, or from squeezing it unduly in fitting it into the container. It is essential in filling that there be some bulge in the center of the box and that the tops when nailed on spring outward and hold the fruit in place. This method would seem to cause injury, but this is not the case unless this bulge in the center is uneven or too high.

378. Wrapping.—In the case of some fruits, there is an advantage in wrapping. Fruits so treated have a bright and

clear appearance when removed from the container. Wrapping prevents bruising and the wrapping material absorbs some moisture. Moisture, as has already been stated, facilitates the growth of decay-producing organisms. The wrapper tends also to isolate any individual fruit to which decay has gained entrance and the injury is, therefore, less general than it otherwise would be.

The operation of wrapping is performed quickly. The packer takes the paper in his left hand and the fruit in his right. He throws the fruit into the center of the paper and with a quick twist wraps it while in the act of placing it in the box. Some packers place with the right hand, others with the left. This placing must be done firmly but at the same time not too roughly.

All fruits are arranged systematically in packing except grapes, cherries, and berries. These are placed in the container without arrangement and then faced; that is, the top layer is packed regularly so as to give the fruit a neat and uniform appearance. When apples are packed in barrels, they are placed without arrangement or assortment in the barrel and the top layer is faced. In some localities in the United States, apples are packed in the same way in boxes. As a rule, however, box-packs are arranged in layers.

These are two common arrangements in the box, the straight and the diagonal. The fruit adjusts itself better to the package with the diagonal than with the straight pack. It is, therefore, the more common system of the two. The number of fruits in a tier will be determined by the size. Oranges are fairly elastic and can be adjusted to the container. Apples are less so and also vary greatly in shape, so that the arrangement of a given size may have to be modified to fit the box. In general, the size of the box has been determined by the best arrangement of the fruit within and, in some cases, more than one size has been adopted to facilitate the packing of different sizes of fruit.

TRANSPORTATION AND STORAGE

Transportation includes shipping, cooling, refrigerating, railway hauling, switching, and unloading; to this is added storing of the fruit if it is to be held for out-of-season sale. At the present time, transportation of crops to market almost always includes a trip by railroad or boat. Fruits shipped from country districts to near-by markets do not require the special care which is necessary in long-distance transportation.

379. The railroad.—The growth of the fruit industry in the United States has been made possible by the development of the railroad. The first trans-continental road was completed in 1869. Others quickly followed. They were built in advance of the needs of the day, but they unquestionably played a large part in hastening the development of the country. Certainly the growth of the fruit industry in the West and Middle West would have been absolutely out of the question had it not been for transportation facilities thus afforded. At first fruit was shipped in small quantities; now a large proportion of the shipments is in carload or trainload lots. Some of the roads run regular trains which carry nothing but fruit and which have the right of way over all other types of service, including in some cases even passenger trains. The volume of fruit and vegetable business handled by railroads has now reached enormous proportions.

380. The time element.—After the grower, the picker, the teamster, the grader, the packer, and the car-loader has each done his part in preparing the fruits for transit or storage, the conditions under which the product is held have an important influence on its keeping qualities. The time required to transport the packed fruit to market varies from a few days to as long as three weeks, during which a very considerable deterioration may occur unless special conditions are provided to prevent it. The time element is most important for the soft and quick-ripening fruits such as berries, cherries,

peaches, plums, and prunes, and least significant in the case of the harder and slow-ripening sorts such as apples, some varieties of pears, and the citrus fruits.

381. The temperature element.—Next to the type of handling given the fruits, the most important factor in their sound transportation to market and storage is the temperature at which they are held. As warmth favors decay, cold checks it. The temperature factor is very important for all fruits, but it would be impossible to transport the soft fruits to market without some means of cooling and keeping them cool during the trip. This is the purpose of the modern refrigerator-car.

382. History of refrigeration.—The refrigerator-car was invented in the middle of the last century but did not come into general use until the decade beginning 1870. During these ten years the meat-packers and shippers adopted the car very generally, and in the next decade, from 1880 to 1890, the shippers of fruit followed their example.

At first objections were raised to the building of these expensive cars on the ground that they could be used for a limited time only in each year. This has not proved to be the case. The season for perishable products opens in the United States in Florida in late winter. The railroads estimate that it then moves northward as the season advances at the rate of about fifteen miles a day. Meanwhile the refrigerator-car follows this advancing season and is used to haul the fruit from each section successively. Finally, the cars which were employed in the beginning of the season to haul the fruit from Florida northward, are used later to carry the northern products southward. It has now been found that in addition to keeping the fruit cool, these cars can be used during the fall and winter in the North for the transportation of products which otherwise would be frozen by the extreme cold. The same construction which in summer excludes the heat is utilized in the winter to keep the warmth in the car.

383. The refrigerator-car consists of an insulated compartment at the ends of which ice is stored. In cooler weather, when ice is not being used, ventilators at the ends of the car are left open. In refrigeration, the cooling of the fruit is accomplished by the circulation of air. The cold air about the ice in the bunkers, being heavier than the warmer air in the body of the car, sinks down and flows outward along the floor, displacing the warmer air, which rises and gradually moves along the ceiling to the ice bunkers where it is cooled and passes downward. Thus there is a continuous air circulation downward through the ice bunkers and upward among the tiers of fruit packages. The cooling capacity of the air is greatest at the bottom of the car, and diminishes as the air passes upward. As the air circulation is due solely to the difference in density or weight of the cold air columns within the ice bunkers and the warmer air in the body of the car, the movements of the air currents are sluggish and, therefore, do not cool the fruit quickly, especially if there is any considerable heat leakage into the car. The amount of heat leakage is determined primarily by the efficiency of the insulation but this is not of the highest type, owing to limitations of cost and weight in car construction. The leakage is naturally greatest when the difference in temperature within and without the car is at a maximum. It is impossible to prevent this leakage entirely even with the best insulation and car construction now in use.

384. Limitations.—The refrigerator-car is not to be considered in the same class with the cold storage warehouse plant. The insulation is not as efficient and the methods of stacking and piling the fruit are such that there is serious interference with the circulation of the air within the car. Moreover, the refrigerating medium (usually ice alone) is not as efficient as the material used in mechanically cooled warehouse plants. For these reasons, the temperature within the refrigerator-car is not as uniform as is necessary for the safe

carrying of fruits for any considerable length of time. Moreover, a high consumption of ice is needed to offset the unavoidable heat leakage.

When the fruit is packed and loaded into the car while warm, there is a very considerable variation in the temperature conditions in different parts of the carload. The warmer air rises to the top of the car, and accumulates in a layer which extends far enough down to affect the upper tiers of packages. It is cool, of course, but not to the same degree as the air below. For this reason, perishable produce cannot be loaded to the full height of the car. Frequently in the case of quick ripening fruits, the packages on the upper tiers arrive in market with considerable deterioration due to over-ripeness and decay, while those in the bottom tiers arrive in sound condition.

The limitations of refrigeration have led to attempts to cool the fruit, or the air in the car or both, before the train starts on its way. Experiments in precooling were conducted by the United States Department of Agriculture, with results that seemed very satisfactory, and this process is now being practiced with oranges. Attempts to precool other fruits have not proved as satisfactory, but it is probable that in the future practical and inexpensive methods will be devised.

385. Storage consists in placing products under favorable conditions for continuing their life activity slowly and thus prolonging their life span. Storage may be carried on according to either of two ways:

(1) *Cold storage* consists in holding compartments or rooms cool by special means, to the lowest possible temperature that will keep the fruit in good condition. This temperature is usually 32 degrees.

(2) *Common storage*, sometimes called dry storage, consists of storing in special rooms or plants; the process depends on ventilation to cool the fruit and hold it in good condition for a longer period than the normal season. There is no artificial

cooling in this method. The fruit cannot be held so long or in such good condition and the process, therefore, is ordinarily not so good as cold storage. Even though the temperature at which the fruit is kept in common storage is fairly satisfactory, the cooling is done much more slowly than in cold storage and this results in quicker deterioration.

386. Essentials of success in cold storage.—Certain essentials must be observed if fruit in cold storage is to be kept successfully for any considerable length of time. The stored fruit must be well grown and of good quality or it will not last; besides, cold storage is expensive and it does not pay to subject any but the best quality of fruit to such a process. Bruises or abrasions of the skin obtained in picking or packing persist in storage and allow decay to get a start. If this does not become manifest while the produce is still in storage, it will do so immediately after it is taken out. If the material to be stored was in poor condition when placed in the warehouse it will be much poorer when it is removed. On the other hand, if it was in good condition and the storage facilities are satisfactory, the chances are that it will be in first-class shape when removed.

If perishable goods are to be kept in storage for any length of time, it is desirable that they be placed there at the earliest possible moment. It is well known, for example, that a delay of ten days in the storing of apples may reduce the storage period from one to three months.

There is a limit also to the length of time that fruit can be held successfully in storage. It is necessary in this connection to inspect the product carefully from time to time and to withdraw it from storage as soon as it shows indication of deterioration.

It is never practical to re-store. Fruit which has once been warmed up after it has been in storage has poor keeping qualities and would deteriorate very quickly even though placed again at a low temperature. It is also true that fruit

does not keep long after withdrawal. It is, therefore, desirable to sell or dispose of it in other ways as soon as possible.

387. Care of storage-rooms.—It is essential that storage-rooms be kept clean and dry. Strong odors are readily absorbed by materials in storage and, therefore, fish, onions, citrus fruits, eggs, celery, and similar products should not be kept promiscuously in the same room. Fluctuations of temperature are exceedingly injurious and should be avoided. Cold storage companies have a regulation that rooms cannot be opened except at stated intervals. Cold storage plants must be so constructed that they are well insulated against the entrance of heat and must be provided with adequate facilities for reducing the temperature to the point desired. If the thermometer drops too low, the commodity in storage will be injured perhaps even more seriously than if the temperature is too high. Theoretically, this temperature should be as near the freezing point of the product as possible without actually freezing. The standard cold storage temperature for fruits is 32 degrees F., but there are some exceptions. For example, citrus fruits are stored at a temperature from 50 to 55 or even as high as 60 degrees, and some varieties of apples are best kept at 35 degrees. In transportation it would be desirable, if possible, to have the same temperature, but it is impracticable to hold cars so low on account of the expense involved. The average temperature of the refrigerator-car is not far from 40 degrees.

It might be supposed that a temperature of 32 degrees, which is the freezing point of water, would injure all fruit. This is not the case, for fruit juices contain various substances in solution which have the effect of lowering their freezing point. A solution of water and sugar will freeze, not at 32 degrees, but at a temperature several degrees lower. The same is true of fruit juices.

388. Advantage of storage.—The storage of fruits is of advantage in several ways. It takes care of a surplus which

would otherwise be thrown on markets carrying already the maximum which the consuming public will buy. It is a benefit to the consumer because it enables him to purchase perishable products out of season at reasonable prices. When carried on in connection with transportation, it makes possible the shipment of fruit and vegetables for long distances at a comparatively slight increase in cost.

Storage plays a double role in distribution; it widens the field and extends the time. The present commercial development of industries dealing in perishable or semi-perishable products would not be possible without storage.

EXERCISES

EXERCISE I.—The packing of fruit.

Materials.—Boxes or crates of fruit such as apples, oranges, or other fruit packed ready for the market.

Procedure.—Open the box before the class and have the pupils make a diagram of each layer as it is removed until the box is empty. Then have members of the class replace the layers, using the diagrams which they have previously made.

EXERCISE II.—Field trip to markets.

Procedure.—Make a study at different markets of fruit as it appears on the stand. Note the general condition of the fruit, the pack, the container, the label, the point of origin, attractiveness of display.

Each student should write a paper for his note-book based on observation on this trip.

EXERCISE III.—Balling test for ripeness of grapes.

Materials.—Balling saccharimeter, glass cylinder, sample of grapes, muslin cloth, glass beaker.

Procedure.—Squeeze grapes in muslin cloth and collect juice in glass beaker. Pour this juice into the glass cylinder until there is sufficient to float the saccharimeter. Note saccharimeter reading together with temperature correction. Make correction as indicated on the saccharimeter and record in your note-book the corrected saccharimeter reading.

Grapes for the fresh fruit market should contain at least 16 or 17 per cent of sugar and those for raisins 24 to 25 per cent. How does this sample compare with the requirement?

EXERCISE IV.—Eight-to-one test for ripeness of oranges.

Materials.—Brix spindle graduated in tenths, beaker, centigrade thermometer, glass cylinder to hold Brix spindle, 10 or 25 c.c. pipette, one burette and support; one liter standard alkali solution, 1 ounce indicator solution, lemon squeezer, large glass or granite cup, straining cloth or wire strainer.

Procedure.—Take a sample of nine to twelve oranges, cutting them in half. Extract juice with lemon squeezer and strain. Introduce juice into glass cylinder until there is sufficient to fill the cylinder. Take spindle reading (being careful to write this down) together with temperature. From the table obtain temperature correction and add or subtract to Brix reading as case may be. This corrected reading indicates the percentage of soluble solids present in the orange juice.

Next determine acid present as follows: Draw off 10 or 25 c.c. of juice into a clean glass beaker. Add some distilled water and several drops of indicator. Pour standard alkali solution¹ into the burette until the upper end of the alkali column is on the zero mark. Now add alkali solution to the orange juice, at first gradually and finally, drop by drop, until a permanent pink color appears. Note the reading of the burette. Multiply this reading by ten and you have the milligrams of acid present in the sample of juice. Next, change cubic centimeters of juice to milligrams of juice by multiplying by 1000 and the specific gravity. This can be found by following the directions under Table II. To obtain the percentage of acid present, multiply milligrams of acid by 100, then divide by milligrams of juice. Now divide the percentage of soluble solids by the percentage of acid and the answer is the ratio.

E. g. Suppose that the Brix reading is 12.6, temperature 13° "C," cubic centimeters of juice 25, and of standard base necessary to neutralize the juice, 36. The problem is worked as follows:

Correction for 13 is .2. This is to be subtracted. 12.6 minus .2 equals 12.4. This answer represents the percentage of soluble solids in the orange juice. The specific gravity of the solution with a test of 12.4 is 1.05021. The weight of 25 c.c. of juice is found by multiplying this figure by the specific gravity: 25×1.05021 equals 26.25525 grams. Change to milligrams by multiplying by 1000; this equals 26,255.25. Multiply 36×10 and $\times 100$ equals 36,000. Divide this by 26,255.25 equals 1.37+. This is the percentage of acid in the juice. Divide the percentage of soluble solids (12.4) by the percentage of acid (1.37); this equals 9.05 and the ratio is 9.05 to 1.

¹To prepare standard solution, dissolve 6.25 gm. sodium hydroxide in enough distilled water to make a liter of solution.

TABLE I

All corrections given below are to be subtracted from the Brix reading:

TEMPERATURE (DEGREES "C")	CORRECTION
0	.46
5	.40
10	.31
11	.27
12	.23
13	.20
14	.16
15	.13
16	.08
17	.03

All corrections given below are to be added to the Brix reading:

18	.03
19	.08
20	.16
21	.23
22	.30
23	.36
24	.42
25	.48

EXERCISE V.—The principle of refrigeration.

Materials.—Two glass beakers, small bottle of ether, 25 c.c. of water, 1-200 c.c. flask.

Caution.—Do not allow a flame of any sort in the vicinity of ether! It is highly explosive!

Procedure.¹—Pour the water into the flask and with this held slanting in the hand, pour ether over the outside into the other beaker. Then pour the ether from this beaker again over the flask into the first beaker. Continue the process until the water in the flask is frozen.

Ether evaporates very readily. When it does so it absorbs heat from the flask. This causes the water to freeze.

The same process takes place in a refrigerator plant except that in this case ammonia which is very much cheaper than ether is utilized. The ammonia extracts heat from a solution of salt and water and this cold brine is then circulated through pipes which are located in the cold storage-rooms.

¹ If the quantity of material available is small or if the room is close, this had better be performed as an instructor's experiment.

TABLE II

Degree Brix (Per Cent Sugar, etc.)	Specific Gravity	Degree Brix (Per Cent Sugar, etc.)	Specific Gravity	Degree Brix (Per Cent Sugar, etc.)	Specific Gravity
9.0.....	1.03599	11.4.....	1.04599	13.8.....	1.05617
.1.....	1.03640	.5.....	1.04641	.9.....	1.05660
.2.....	1.03682	.6.....	1.04683	14.0.....	1.05703
.3.....	1.03723	.7.....	1.04726	.1.....	1.05746
.4.....	1.03765	.8.....	1.04768	.2.....	1.05789
.5.....	1.03806	.9.....	1.04810	.3.....	1.05874
.6.....	1.03848	12.0.....	1.04852	.4.....	1.05917
.7.....	1.03889	.1.....	1.04894	.5.....	1.05960
.8.....	1.03931	.2.....	1.04937	.6.....	1.06003
.9.....	1.03972	.3.....	1.04979	.7.....	1.06047
10.0.....	1.04014	.4.....	1.05021	.8.....	1.06090
.1.....	1.04055	.5.....	1.05064	.9.....	1.06133
.2.....	1.04097	.6.....	1.05106	15.0.....	1.06176
.3.....	1.04139	.7.....	1.05149	.1.....	1.06219
.4.....	1.04180	.8.....	1.05191	.2.....	1.06262
.5.....	1.04222	.9.....	1.05233	.3.....	1.06306
.6.....	1.04264	13.0.....	1.05276	.4.....	1.06349
.7.....	1.04306	.1.....	1.05318	.5.....	1.06392
.8.....	1.04348	.2.....	1.05361	.6.....	1.06436
.9.....	1.04390	.3.....	1.05404	.7.....	1.06479
11.0.....	1.04431	.4.....	1.05446	.8.....	1.06522
.1.....	1.04473	.5.....	1.05489	.9.....	1.06566
.2.....	1.04515	.6.....	1.05532	16.0.....	1.06609
.3.....	1.04557	.7.....	1.05574		

To obtain specific gravity, first find Brix reading, then make correction for temperature; then take next reading found in the left hand column of figures in table above and note opposite the specific gravity in the right hand column. E. g. If the Brix reading is 11.4 and if the temperature is 22° "C.," then the temperature correction is .3 and this correction is to be added. Adding .3 to 11.4 gives 11.7 and the specific gravity for orange juice whose Brix reading is 11.7 is 1.04726.

EXERCISE VI.—Cold storage.

Procedure.—If there is a cold storage plant within a reasonable distance of the school, the class should visit it, noting such points as

the following: Size, cost, method of cooling, products stored, length of time they have been in storage, general condition, cost of storage, regulations regarding withdrawal, benefits to producers, benefits to consumers, state laws governing cold storage. Notes should be taken on the trip and this should be followed by a discussion the following day in class, after which each student should write up a complete account for his note-book.

CHAPTER XIX

MARKETING

THE preparation for market and transportation normally precede the marketing and selling stage. But this is not always the case. Sometimes the fruit is sold on the trees or sales may be local, to country merchants, or direct to the consumer. Sales direct to the consumer are by house-to-house peddling, or through the public markets. Sales to distant points may be made f. o. b. shipping point, which means that the buyer pays the freight; or they may be on the "delivered" basis, where the shipper pays transportation charges.

Some of the common agencies in the marketing process will be considered in the following pages.

389. Commission-men.—Sometimes fruit is handled on the commission basis. That is, it is shipped by the producer to an individual or a firm in a large city to be sold in consideration of a certain fixed percentage of the selling price. The commission-man generally sells direct to the retailers, that is, to the stores, venders, peddlers, and the like, and occasionally through an auction company. The fruit does not at any time become the property of the commission-man but is handled by him as an agent for the grower. He sells the fruit, collects the money, and remits the sale price, minus the commission, to producer. There has been a large amount of dissatisfaction with this system. The opportunities for dishonesty are very great, because the grower finds it almost impossible to keep a check on either the condition or the disposition of his fruit. The commission business as a whole

has, therefore, fallen into disrepute. Many commission houses, on the other hand, have built up for themselves reputations for honesty in all their dealings which have enabled them to continue despite the growing suspicion concerning the commission business as a whole. Furthermore, many farm products, especially fruits and melons, are of such perishable nature that dealers in the city are unwilling to receive them by outright purchase. They insist that the risk be assumed by the shipper, and this leaves the commission method almost the only alternative. There has been a tendency in recent years to pass laws subjecting the commissionmen to rigid accounting in all their dealings both with producer and retailer, and the effect will unquestionably result in good, alike to the producer and to the honest commissionman.

390. The broker.—A broker differs from a commissionman in that he deals in large quantities, and has regular customers among both buyers and sellers. He is located, as a rule, in a large city, where he becomes thoroughly acquainted with market conditions, thus being able to sell the produce at the best figure. He does so in the name of the shipper, receiving a fixed compensation for his services. The shipper is sometimes the producer and sometimes a local buyer or speculator, who may or may not have bought the fruit on the trees. The broker's compensation is usually so much for the car, box, or crate. This method of sale usually works out satisfactorily for all concerned but is limited, as a rule, to the larger shippers. Ordinarily the broker sells to the jobber.

***391. The jobber** buys in large quantities from the producer, a local buyer, or through a broker, and sells to the retail trade. The jobber is necessary under the present marketing system because he breaks up the large lots. In doing so, he assumes a number of responsibilities: (1) He guarantees to the shipper payment for the fruit received.

(2) He sees to it that transportation is supplied for delivering the fruit to the retail stores. This calls for a well-developed delivery system in the large cities, for the retail stores buy frequently and in small quantities. (3) The jobber becomes an expert in brands of fruit received from different sections of the country and from separate packing-houses in the same region. Very frequently these brands are demanded year after year by certain retail stores; the jobber thus acts for them in seeing that a constant supply of the products desired is always on hand.

392. Sale by auction.—In seventeen of the large cities of the United States, one or more auction markets are maintained for the sale of fruit. These have come to play a very important part in establishing fruit prices throughout the country. In the main, the fruits sold at auction are those which will not stand storage for any great length of time. The auction market acts quickly. Fruit is received by the carload and enough boxes opened and examined to give a fair idea of the contents of the car. The carload is then sold to the highest bidder. This method cannot be successful unless there is a large quantity of fruit on hand regularly, of a given kind and standardized to an extent that will indicate rather definitely the quality of the commodity. These conditions alone will attract the large number of bidders necessary. This method of sale is not adapted to the small shipper who sends his fruit at irregular intervals. Auction markets sell to jobbers and retailers.

393. Defects in the marketing system.—The same lot of fruit frequently goes through the hands of many dealers of one sort or another before it reaches the consumer. The charge is often made that there are too many middle-men, each demanding a profit from the handling of the fruit, and that the system results in a high price to the consumer and a low return to the producer. The tendency to consider all the profits to middle-men as unearned is hardly fair. The

middle-men are searching for channels by which fruit can be put before the potential consumer. They hold and finally transfer fruit to points where it seems to be in demand, usually buying in large quantities and selling in smaller. If a dozen middle-men handle produce more cheaply than could one or finally find a market for what otherwise might be wasted, there is justification for each of the twelve. But that a great deal of confusion and waste exists under the present system is undeniable. Moreover, from time to time abuses of the system have arisen and have threatened the growers very gravely. Sometimes buyers have combined to agree on a maximum price to be paid the growers, with the result that all the fruit had to be sold at a low price, and sometimes jobbers have combined to contract for all the space in warehouses of large cities. Commission-men have been known to repack products into more boxes than the growers used, returning the proceeds for the original number to the producer and keeping for themselves the profit from the extra boxes thus obtained. Commission-men and brokers themselves have turned jobbers, and while extracting from the public the maximum prices have returned to the grower the minimum.

394. Coöperation.—When the present marketing system has given the farmer a fair return on his investment, he has shown himself reluctant to turn to other methods. When for any reason this system has failed, growers have sought protection through the passage of laws (such as those restricting the action of railroads and commission-men) and through organization into coöperative societies. A coöperative organization is a combination for mutual benefit of individuals engaged in similar work or business.

395. Essentials for success in coöperative marketing.—Since the coöperative organization has for its purpose the benefit of all its members, it is necessary that the problems and needs of its constituency be alike, in order that what will

benefit one will necessarily serve all. The successful coöperative organizations have been those which have confined themselves to one crop or to one particular line of activity. For example, an organization for the marketing of poultry should not attempt to engage in handling apples; dried fruits should be kept separate from fresh ones; and citrus fruits from those of the deciduous varieties. The crop handled by any one organization should be of about the same kind and quality and produced under somewhat similar conditions.

The second essential is that the membership be held together by the strongest possible ties. The first of these is the bond of a common necessity. Where the coöperative organization has not filled an imperative need, it has proved a failure. The necessity may arise from lack of marketing facilities on account of geographical location or other circumstances over which the grower has no control. It may result from collusion among buyers, whereby the grower is prevented from receiving a fair rate for his product. It may be due to unequal distribution of the product which results in the growers competing one with the other for the market to the detriment of all. There may be need for the reduction of cost of handling, for this is sometimes the determining factor in the success of an horticultural enterprise. In the case of many agricultural products, an increase of consumption is necessary which the individual grower, acting by himself, is unable to bring about. Again, the product may require grading and packing facilities which the individual cannot supply. Whatever the need for coöperation may be, it must be so obvious as to be its own best argument.

Another tie which helps to hold the members of a coöperative association together is that of mutual confidence resulting from personal acquaintance. For this reason, each community should preserve its individuality and not go too far afield in the selection of members. Personal association will cause each member to feel more keenly his responsibility

to the others in times of stress and depression. When it has seemed desirable to organize on a basis larger than that of the neighborhood, it has been found practicable to affiliate local organizations in a central confederation.

396. Benefits.—A coöperative organization may perform many services for its members and the public. The distribution of the product is in the hands of the producer and is in his interests. The organization may be sufficiently powerful to hunt out new markets when those already existing are insufficient for the product. It may extend the marketing period by furnishing its members adequate storage facilities for perishable products until such time as the regular seasonal supply has disappeared. It may reduce the cost to the consumer by delivering the product in good condition at the time and place it is needed and by eliminating many intermediate dealers. It may standardize pack and establish uniform grades so that buyers can be assured of the quality of the goods they are purchasing and thereby be encouraged to buy in larger quantities and at more frequent intervals. It may prevent loss through disease and decay by making a careful study of each phase of picking, packing, and handling of the fruit or other product. Such organizations have prevented exploitation of growers by shipping companies, marketing agencies and transportation concerns, and have protected them also against exorbitant charges by the warehouse interests.

397. Difficulties.—The path of the coöperative organization is strewn with difficulties. It must be democratic in form and mode of operation in order that each member may feel that he is on an absolutely equal footing with every other, and that there are no secret arrangements whereby one member benefits more than another. At the same time enough power must be given the leaders of the organization or the manager to make the carrying out of a constructive business program possible. The choice of a manager is always a

critical step in the progress of a coöperative organization. A high degree of integrity, tact, and trained executive ability, is required for the successful conduct of so complex a business.

The organization is likely to be subjected to considerable pressure from without. Adverse interests encourage members to break away by criticising the management or by promising larger returns for a season than are justified by the condition of the industry. There is always a certain proportion of the membership which will listen to such propaganda and withdraw, leaving the brunt of the fight to be borne by those who remain.

398. Extent of coöperative marketing.—The coöperative marketing system has been applied successfully to many fields. In California, coöperative organizations have been formed by the growers of citrus fruits, walnuts, almonds, lima beans, celery, and cauliflower. In Maine, Delaware, and Maryland, the potato-growers are organized, and in Colorado the producers of cantaloupes. The fruit-growers of the Northwest have organized in groups according to the kind of fruit raised. In Minnesota the shippers of live-stock are organized. The list of coöperative associations is growing rapidly in all parts of the United States.

399. An example of coöperative marketing.—One of the largest coöperative organizations in the United States is the California Fruit Growers' Exchange (see Figs. 134, 35), which handles the orange and lemon crop. The organization markets the fruit of eleven thousand growers. These producers are separated into one hundred ninety-seven neighborhood associations, each of which owns a packing-house. These are in turn organized into twenty district exchanges and these again are affiliated in one central organization, whose place of business is in the city of Los Angeles.

The exchange has as its field of operation the whole of the United States and many parts of Canada. It must be informed of the market situation as it exists from day to day

throughout this vast territory. To do this, it maintains seventy-seven district offices which are in touch with twenty-five hundred jobbers. These jobbers in turn deal with three hundred thousand retailers and these latter furnish California oranges and lemons to one hundred twenty-five million consumers in the United States and Canada, the return value of whose products in the wholesale markets is between seventy-five and one hundred million dollars.

The organization furnished supplies to its members amounting in one year to over six million dollars. It has purchased a tract of timber lands aggregating more than forty-one thousand acres, which will insure a supply of lumber for box shooks sufficient for the next fifty years. It maintains an advertising department which has made "Sunkist" a household word wherever oranges and lemons are bought. It has organized a by-products company which extracts citric acid and other valuable by-products from worthless lemons and which is now devising ways of utilizing all fruit of good quality, but inferior in appearance, in such manner that the growers will receive a maximum return for the product.

In addition to these, the traffic, legal, and field departments, each in its own particular province, secure benefits to the growers which they could not possibly obtain for themselves.

400. Market information.—The California Fruit Growers' Exchange maintains, as already indicated, seventy-seven sales offices throughout the United States and Canada. These agents must each day collect information and transmit it to the central office in Los Angeles, and this office in turn, on the basis of this information, directs the shipment of its fruit. A specimen telegram from one of these eastern points to the central office in Los Angeles will illustrate the sort of information collected each day: "Ship as soon as possible 60/126s, 120/150s, 120/176s, 40/200s, 40/216s, 20/250s, Martha Washington Valencias, \$2.75. Rather coarse quality, some very green S. A. 2936. Overdue

and not arrived, railroad over which car is routed cannot locate A. C. G. 2366. If we cannot sell tomorrow where shall we divert O K 3003? Temperature 50 degrees above zero, 11 A. M. Weather Bureau predicts favorable weather." The meaning of this telegram is as follows: "Ship to this

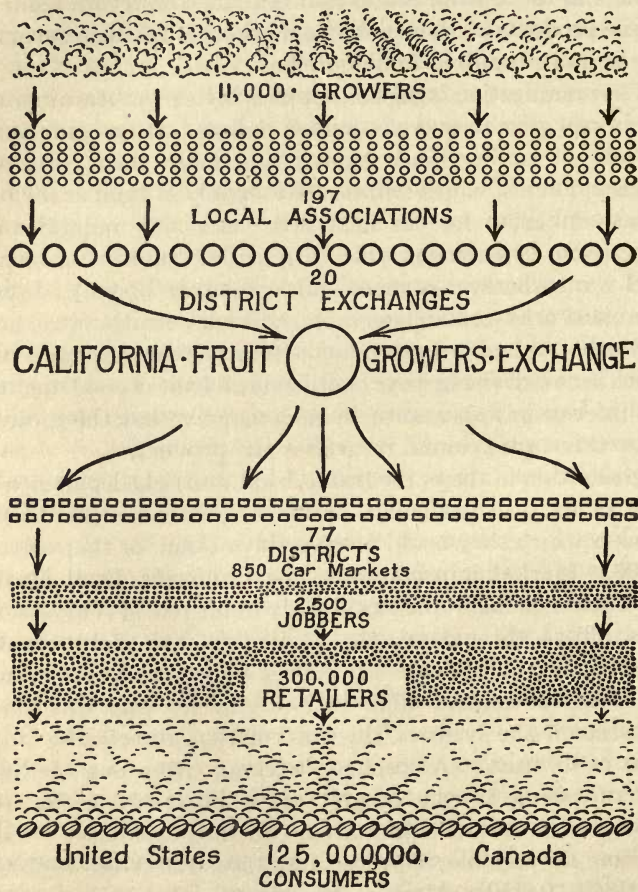


FIG. 134.—Steps in distribution of fruit by the California Fruit Growers' Exchange.

point as soon as possible, sixty boxes of oranges, each containing one hundred twenty-six oranges to the box, one hundred twenty boxes, each containing one hundred fifty oranges . . . these oranges to be of that particular grade known as Martha Washington Valencias. I can sell these at \$2.75 per box. A car of oranges shipped from the S. A. (San Antonio) district exchange arrived in rather poor condition; most of the fruit was green, and rather coarse in quality. Car No. 2366 from the A. C. G. (Azusa-Covina-Glendora) exchange has not arrived and we cannot locate railroad over which it was routed. Car No. 3003 from the O. K. (Ontario-Cucamonga) exchange has been routed to this point; if we cannot sell it here, to what other city shall we divert it? Temperature is fifty degrees above zero, at eleven o'clock this morning. The Weather Bureau predicts favorable weather."

Seventy-seven telegrams of this same sort are received each day in Los Angeles from the seventy-seven different selling organizations stationed throughout the United States and Canada. On the basis of this information, the sales office in the exchange in Los Angeles sends out directions to each of these offices telling them what to do under the circumstances, and advises them of any fruit which may be en route to them. Meanwhile, copies of these incoming and outgoing telegrams are sent to each of the nineteen district offices in southern and central California and the managers act in accordance with the information thus received. Thus, each of the various districts of California is kept in contact with actual market conditions throughout the country.

401. Cost of marketing.—There has been much speculation and heated controversy regarding the cost of putting agricultural and horticultural products in the hands of the consumer. At present, the United States Government has marketing experts engaged in collecting information along this line, and within a few years probably more will be

known concerning this subject. The California Fruit Growers' Exchange has been collecting information since December, 1913, and its results are shown in the diagram (Fig. 135). To quote the language of the exchange: "Our agents have tabulated the delivered price to jobbers of oranges of varying sizes. They have also tabulated the price at which the leading jobbers have charged the retailers and then determined the price which the retailer charged the consumer. They have

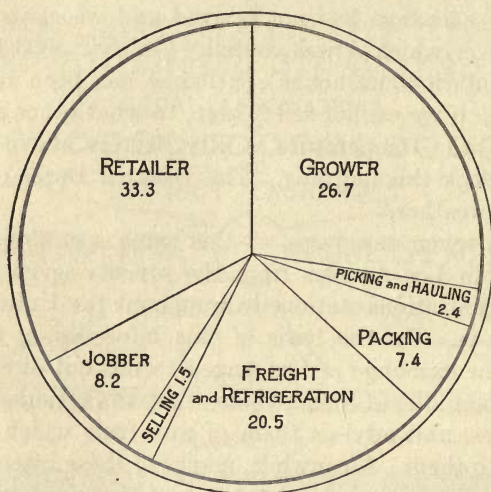


FIG. 135.—Distribution of gross proceeds of citrus sales. An analysis of what becomes of the consumers' dollar.

then put the results in the form of a diagram which represents the consumers' dollar. This diagram shows what has become of the amount paid by the consumer."

According to these figures, the retailer kept 33.4 cents of each dollar which he received in the year 1914; in 1915 his share was 28.1 cents, in 1916, 25, and in the year 1917, 29.2 cents. The jobbers' margin, as shown in the diagrams, has varied from 8.8 in 1915 to 9.9 cents in 1916. Freight and

refrigeration cost 21 cents in 1914 and 18.9 in 1916. During the other two years, the figure remains between these two. The sale cost which represents the proportion which goes to the coöperative organization has remained each year as 1.2 cents; packing 7.3 cents in 1914 and 6.4 in 1916. Picking and hauling has cost about 2.2 cents each year. The fruit has, therefore, netted the growers during these four years the difference between the totals given here and one hundred. That is, of the dollar which the consumer paid, the grower received 25.9 cents in 1914; in 1915 his share was 34.6; in 1916 it had risen to 38.9 and in 1917 it was 33.2 cents.

It should be remembered in connection with these figures that they deal with a very perishable product which is marketed in most cases several thousands of miles away from the point where it was grown at a season of the year when loss from decay is likely to be very large.

Studies of this sort have a great value in determining the exact facts regarding the cost of marketing and in suggesting the points at which improvements may be made. Those phases of marketing which at present are weak may in this way be strengthened. The charge of profiteering so frequently made can be proved if it really exists, and if it does not the marketing organizations will be freed from the incubus of an undeserved accusation.

CHAPTER XX

INCIDENTAL PRODUCTS

A **BY-PRODUCT** is some substance or article produced in the course of a process of manufacture, in addition to the principal product or material. It frequently happens, however, that the by-products become of more importance than the primary substances themselves. There is hardly a line of manufacturing of any importance which does not yield by-products; the elimination of waste is one of the great problems of the day.

402. Some examples of by-products.—One of the most interesting fields for study of by-products is that of illuminating gas. This is ordinarily obtained by heating coal in a closed retort. The heating process drives off a large number of substances, leaving behind the solid coke, an article that has become exceedingly important in many fundamental industries. Later, in the process of purification of the illuminating gas, other by-products are obtained, such as ammonium sulfate, which is used as a fertilizer; acetic acid, the substance which makes vinegar sour; benzene and carbolic acid, familiar to all; the cresols, used as disinfectants; picric acid, one of the most important materials in the manufacture of explosives; aniline, the source of the best dyes; and asphalt, used in paving roads and streets. The list is given to indicate the importance of utilizing what once were considered waste products, having no value whatever.

403. By-products in horticulture.—The record of achievement already indicated in the illuminating gas industry can be repeated in many other fields. In horticulture itself there

are great possibilities. There are produced every year millions of gallons of cider, immense quantities of jelly from apple peelings, prussic acid from apricot pits, alcohol from waste products such as worthless potatoes and fruit pulp, marmalade from cull oranges, citric acid and lemon flavoring extract from cull lemons, sirup, oil, extract of tannin, and raisin-seed meal from raisins, and many other by-products. A few years ago these would have been discarded as worthless, yet now their value runs into millions of dollars annually. The instructive and interesting feature, however, is that the present number of horticultural by-products represents a beginning only. The annual losses are still immense; each loss is a challenge to the intelligence of the trained horticulturists of America, and as time goes on new by-products will be constantly added to the list.

404. Vinegar manufacture.—Apple cider contains a certain amount of sugar, which, if unmolested for a brief time, changes into alcohol. This change is brought about by the action of bacteria on the sugar. The alcohol in turn is transformed into acetic acid by another set of bacteria. Although other substances besides acetic acid are present in commercial vinegar, acid is the essential in the final product.

If home-made vinegar is examined closely, a scum will be seen over the top of the mass, a dark-colored substance which is commonly known as “mother of vinegar.” This mass is nothing more nor less than a collection of large quantities of the acetic-acid-forming bacteria; and whenever a new lot of cider is to be changed to vinegar, the process is hastened by adding some of the “mother” to it.

Several species of bacteria have the power of changing alcohol into acetic acid, all of them differing slightly in regard to conditions under which they live. Since some of these species are better than others, the makers of vinegar are at present endeavoring to sort out the more favorable types to

the end that these may be utilized exclusively in vinegar production. The use of these pure cultures will without doubt result in a superior product.

Vinegar is commonly manufactured by the quick method. Vats are filled with beech-wood shavings, over which grain alcohol diluted with vinegar is allowed to trickle. This introduces bacteria throughout the shavings. A substance containing alcohol, such as hard cider, which is to be transformed into vinegar, is then allowed to percolate through these vats. As it does so, the alcohol is acted on by the bacteria and changed into vinegar, which is drawn off at the bottom of the vats.

405. Olive oil.—The olive is a fruit the poor grade of which can be used to excellent advantage in the preparation of a product of considerable commercial importance. Olive oil has been used by man from the time of earliest recorded history and remains today one of the important commercial products.

The oil is extracted from the pulp by a two-fold process of crushing and pressing. The crushing was done formerly by means of a crude grinder operated by animal power. At the present time, the fruit is first partially dried and then crushed by power-operated rollers. The pulp is inclosed in layers of stout cloth and placed on a hydraulic press.

The first oil which comes off the press is a high-grade commercial product used only for the fancy trade. As pressing continues, the oil becomes poorer in quality and commands a correspondingly lower figure on the market. With present facilities, a considerable part of the oil still remains unextracted from the pulp, a circumstance which calls for an intensive study of the whole problem. Since that part which is extracted has a very considerable value in the aggregate, and since by this means the poorer grades of fruit are utilized, the industry is one of genuine economic significance.

PRESERVATION BY DRYING

The changes that are produced in fruit after it becomes ripe are of two sorts; the first is chemical, the second bacterial.

406. Chemical changes.—In all cells certain chemicals known as enzymes are present. These act on the substances in the cells, producing changes in them. For example, some enzymes in the muscles of animals cause softening of these muscles after death while others break down the tissues and bring about a ripening of meat whereby it becomes tender.¹ Certain enzymes in fruits attack the carbohydrates or the proteins, producing changes which destroy the value of the product. If the fruit is to retain its natural flavor, the action of these enzymes must be prevented. This can be done either by heating or by drying.

407. Bacterial changes.—It has been seen that wherever food, moisture, and warmth are present, bacteria are sure to abound unless they have been previously killed or excluded. To preserve fruit from bacterial action, therefore, it is necessary either to remove the heat or the moisture. The former process is cold storage; the latter, drying or evaporation.

408. The fruit-drying industry.—Where the climate is sufficiently dry to remove the moisture quickly, fruit is cured by the simple device of laying it on trays out-of-doors. In the case of common stone-fruits such as peaches and apricots, the pits are first removed and the fruit then halved and placed on trays in the sun. The trays are left exposed to the sun for a period, then are gathered up, piled on small cars, and run into air-tight buildings, called sulfuring houses. Here the partially dried fruit is subjected to the fumes of burning sulfur for periods varying from two to twelve hours, about one pound of sulfur being used to a ton of fruit. This sulfur-ing process is useful in two ways: It improves the appearance

¹ Marshall's Microbiology.

of the fruit, and it prevents the growth of bacteria and fungi. Fruit is not dried so completely as to remove all the moisture; nor can it always be kept in perfectly air-tight containers; it is, therefore, always slightly moist, thus making possible the development of decay-producing organisms. Sulfur, however, prevents the growth of such structures, and is used wherever fruit is preserved by drying.

409. The chemistry of sulfuring.—When sulfur burns in air, it unites with oxygen, forming a new substance known as sulfur dioxide. This has the peculiarly pungent odor so characteristic of burning sulfur. Sulfur dioxide gradually comes in contact with the moisture of the fruit, forming sulfurous acid, which, on being exposed to the air, unites with oxygen forming sulfuric acid. All sulfured dried fruit, therefore, contains a certain amount of sulfuric acid and a lesser amount of sulfurous acid. When the pure food and drug act was passed in 1906, the chemists in charge of its enforcement feared that these acids in the fruit rendered it injurious to the consumer. Fruit-growers immediately realized that, if sulfuring were not allowed, their industry would be destroyed; for sulfuring not only improved the appearance of the fruit, giving it an amber-like color when dried, but also prevented the growth of bacteria and fungi and kept away injurious insects, which would otherwise destroy large quantities. The matter was submitted to a board of experts and after careful investigation it was found that the acids present in moderate quantities were not injurious. The Government has, therefore, permitted the treatment of all dried fruits with moderate quantities of sulfur dioxide gas.

410. Drying of other fruits.—The drying of prunes and raisins differs from that of other fruits, as they contain sufficient sugar to permit of being dried without the removal of the pit or seeds. In the case of prunes, it is necessary first to crack the skins so that the water can escape rapidly. This is done by dipping the prunes for a few minutes in a solution



Plate VIII.—Twig of *Spiraea Vanhouttei* in blossom.

of lye made by dissolving one pound of concentrated lye in ten gallons of water. They are then rinsed in clear water. Grapes for raisins are cured in much the same way. Sometimes they are previously dipped in lye, but usually not. The seeds are removed by special machinery. The work of removing raisins from the stems, packing, and so forth, is also performed in the main by machines.

411. Effect of drying on the industry.—The process of drying is a great stabilizer for the fruit industry. By far the greater part of the fruit is sold to the canneries or to the fresh fruit markets. If, however, prices are extremely low, the grower may hold his fruit by drying, and market it at such future time as he sees fit. This prevents a glut on an already overstocked market. On the other hand, the canneries and fresh fruit trade use only the choice product. The small-sized fruits which are in all respects as wholesome as the larger, but which are unsuited for canning or immediate sale, may then be prevented from going to waste by the drying process.

In those sections of the country in which the climate does not permit of drying, much attention is being given to the construction of special buildings known as evaporators. In these buildings large quantities of fruits are dried by the use of artificial heat, and much which otherwise would be wasted is thus saved for human use. The drying of fruit in evaporators is independent of weather conditions, requires fewer trays to the ton of dried product than when the fruit is dried out-of-doors, produces a cleaner product than is obtained out in the open where more or less dust and dirt sticks to the fruit, and makes it easy to secure a uniformly dried product. For these reasons, the evaporator method of drying is sure to become increasingly popular, even in regions now producing exclusively sun-dried fruits.

EXERCISES

EXERCISE I.—Fruit drying.

Materials.—Fruits suitable for drying, such as apples, pears, peaches, apricots, prunes, grapes, figs; trays and other utensils necessary for drying fruits.

Procedure.—(1) Pack, cut, and dry the fruit according to the methods discussed in the text. Record the weight of the fruit before and after drying. Obtain the market quotations for the fresh fruit. On the basis of the value of 100 pounds of fresh fruit, compute the price a pound of the dried product which would have to be realized in order to make drying profitable. (2) If you can obtain them, dip and dry some prunes. (3) Secure some fresh raisin grapes and dry them. (4) Compare your dried specimens with some obtained from the market.

EXERCISE II.—Study of dried fruits.

Materials.—Samples of dried fruit.

Procedure.—Examine as many samples of dried fruit as possible. Notice special packs, and the like. Note differences in sample. Compare them as to size, appearance, quality.

EXERCISE III.—Study of by-products.

Materials.—By-products from the fruit industry.

Procedure.—Bring to class samples of as many kinds of horticultural by-products as you can obtain. Be prepared to explain how each is made. The samples brought by the whole class should make a varied and interesting collection.

EXERCISE IV.—Making by-products. It is suggested that the class make one kind of horticultural by-product, such, for example, as vinegar, or olive oil. The choice of by-product will be determined by the locality.

CHAPTER XXI

THE USE OF ORNAMENTAL PLANTS

LANDSCAPE-GARDENING is the art of so arranging trees, shrubs, lawns, and other features of a landscape as to produce an effect pleasing to the eye. In its more pretentious sense, it signifies the laying out of large tracts of land, including sometimes hundreds or even thousands of acres, as parks and private estates; but the term is also applied to the ornamentation of home and school grounds occupying even so small an amount of space as a portion of a city lot. The element of artistic design and subdivision of grounds enters largely into the practice of the landscape art.

There are several reasons why every student of horticulture should have at least a slight knowledge of the practices and materials employed in the processes of landscape-gardening:

1. He should be able to plan ornamental plantings for his own home grounds, for such features have both an æsthetic and economic value.

2. He should know something of the concepts governing such plantings, whether the space be small or large, in order that he may appreciate what others have done.

3. He should know the common ornamental material of his locality, for the mere ability to name the plant will of itself give him a perpetual interest in it, and also lead him to a knowledge of its adaptabilities.

A complete understanding of landscape-gardening calls for many years of close study; for there are technical details that are exceedingly complex and difficult. It is possible, however, to state some of the fundamental considerations in

the brief space of a chapter; and if the novice studies and observes these elements, he will not go far astray in the work he may undertake, although he may not make an artist of himself.

412. The plan.—No work should be undertaken until every detail has been worked out and set down on paper. If the buildings have not yet been constructed, their proposed position should be indicated. All features of a permanent character should be included. There must be a drawing to a scale sufficiently large to show the relative sizes of all the material to be used. Shrubs, trees, lawns, walks, drives, flower-beds, and other features will be included in the drawing. The shrubs and trees will be designated by number and the numbers and names indicated on a separate sheet. The location of each shrub and tree is shown by a small half circle.

413. The lawn.—The heart and center of the usual landscape is the lawn or an open space. This was learned from nature, and has been utilized for so many years that its importance has now come to be very generally recognized. Every care must be exercised, therefore, to have the lawn fine and as free from defects of every sort as possible.

414. Shrubbery.—The finest effects are secured when one approximates most closely nature's ways. In nature shrubs are almost invariably in masses; only rarely do they occur as isolated specimens. When shrubs are set, therefore, they should be grouped, putting enough plants together so that the effect will be of a mass, not a collection of individuals. Occasionally a single shrub may be placed by itself; but this will be the exception rather than the rule, and will be dictated only by exceptional circumstances.

Different kinds of shrubs may be blended together in the same shrubbery group, thus avoiding a dull uniformity; but care must be taken that the shrubs are of such nature that they will harmonize. A willow, for example, would not look well with a cactus, even though each might be attractive by

itself. The foliage and habit of growth of the different members of a group should also be in harmony, and if the shrubs bear flowers which are at all conspicuous, conflicting colors should not be placed together. Shrubs should also be graded as to size, the higher in the background, the lower about the outer edge. In some cases, however, the best effects are produced by bold lines or masses of one species of plant.

415. Shrub planting.—When shrubs are set out, they should not be placed too close together, lest the effect be so compact as to appear artificial; room also must be left for convenience in irrigation and cultivation. At the same time, the distances between them must not be very great. There is a happy mean which differs for the various shrubs, localities, and soils, and which must be learned by experience. In general it may be said that shrubs set two to four feet apart grow quickly into a single group; if they seem to be too close together as they grow older, a part may be removed.

Usually the individual plants should be set in such a way as to avoid any suggestion of straight lines. In orchards the trees are desired in rows, but ornamental gardens are more pleasing when the planting does not suggest artificial arrangement.

416. Trees.—From the standpoint of the landscape-gardener, there are two kinds of trees, those with round tops like the oak and elm, and those with pointed tops like the pine and fir. The trees with round tops are, of course, to be preferred where shade is desired; in general, the pointed-topped trees excel in beauty and symmetry of form.

Each tree must be studied for what it connotes or suggests. The oak, for example, possesses an atmosphere of strength and repose. The palm suggests the oasis of the desert. The Italian cypress is more or less formal in appearance, and should be used only where the treatment calls for such formality. Whenever trees or shrubs possess singular beauty or charm as specimen plants, they should be set by them-

selves, apart from the groups; and their beauty may be still further emphasized by planting groups of trees or shrubs to serve as a background.

417. Buildings.—The architecture of the building will determine largely the nature of the plantings to be used about it. A rich formal style of architecture will demand plants of similar nature: columnar trees, like the Irish yew and Italian cypress; compact shrubs, like clipped specimens of English laurel. The less pretentious buildings will call for less formal treatment. Almost without exception, the base of the building should be hidden by shrubbery. The entrance may be emphasized by higher-growing clumps of similar material; the corners may be screened by upright growing shrubs or small trees. The shrubbery should be planted in irregular lines, groups of higher growing specimens appearing here and there.

418. Walks and drives should, wherever possible, be laid out in curves rather than straight lines, as they are less conspicuous and lead restfully from point to point by unnoticed gradations. Further, if the plantings have been judiciously placed, there is in the plan the element of surprise, as a turn here or an opening there reveals some vista not perceived before. If the curve of the walk is unduly sharp, there must be clumps of shrubbery on the concave side.

However, the basic fact that a straight line is the shortest distance between two points should never be lost sight of in walk construction; and the curves should never give the appearance of being forced or abnormal or located in the wrong place. From the standpoint of the landscape, the effect would be more beautiful if walks and drives were dispensed with altogether; but since this is quite out of the question, they must be as beautiful and restful as possible, without ever forgetting the element of convenience.

419. Straight lines.—It has already been stated that straight lines should be avoided wherever possible. At the

same time, there are circumstances that call for the contrary treatment. For example, the trees planted in parkings as borders to streets or avenues should be arranged in rows parallel to the walks or drives to which they are adjacent. The general rule is this: When the artificial feature, such as the walk, or avenue, is the dominant note of the landscape, the plantings must conform to it. It is to be remembered, however, that the skilful gardener makes the walk or drive subordinate wherever possible, and arranges his plant material accordingly in a natural way.

PLANT MATERIALS

One of the first questions that will arise will be: What should be planted here? And this immediately calls up the entire problem of plant material. There are at present many thousands of plants under cultivation. It would, of course, be difficult for any one person to know all or even most of them; and also the greater number are adapted to particular localities or situations only. For all practical purposes it suffices, therefore, if the plants that have proven most useful in the student's own locality be studied and their names and characteristics learned.

In studying these plants, one should not think that a book is absolutely necessary. Some such work as Bailey's *Standard Cyclopedia of Horticulture* is of course useful; but the student should learn also to study the plant itself, noting the general characteristics: height, color of foliage and flower, habit of growth. He should study the leaves, flowers, branches, all parts of the plant, and should become so familiar with it that he can name it wherever seen. Then he should think of it in connection with the landscape—what plant it harmonizes with, what situation it is best adapted to. The process is slow and laborious, but very much worth while.

It may be in order here to mention briefly a few desirable

plants for landscape-gardening, not to suggest specific plants, but merely to call attention to some of the material available in practically all parts of North America.

420. Climbing vines.—No single feature of landscape-gardening can add more to the attractiveness of the average home than a judicious use of climbing plants. They cover the harsh outlines of buildings, or screen porches and windows from the glare of the midsummer sun. The foliage, by its constant evaporation of moisture, assists in keeping down the temperature, and supplies the fresh green so beautiful to the eye.

As a rule, climbers are easy to start, and require little care once they are well established. There are both evergreen and deciduous forms, so if the buildings are too damp or dark in the winter, the deciduous kinds may be used. Some cling by vacuum cups or mucilaginous excretions, others fasten themselves to objects by tendrils or by twining about them, while still others have to be supported on trellis work. Here again there is ample latitude for choice.

421. Boston ivy.—One of the best climbers is the Boston ivy. The technical name is *Parthenocissus tricuspidata*; in parts of the country it is sold under the name of *Ampelopsis Veitchii*. It is deciduous, although there is now an evergreen form on the market. The plant is a member of the grape family. The leaves resemble somewhat those of the wild grape, and the little clusters of small berry-like fruits suggest strongly miniature bunches of grapes.

Boston ivy grows to a great height, clinging to walls by means of tendrils which secrete a mucilaginous substance. It has a wealth of glossy green foliage which persists during the greater part of the year.

422. Virginia creeper, *Parthenocissus quinquefolia*, is closely related to the Boston ivy. (*Quinque* means five; and the name is derived from the fact that the leaves are compound, having five leaflets.) This plant does not cling so

tenaciously as does the Boston ivy; but it makes a heavy growth of foliage, and is frequently used as screening for porches or in situations requiring a heavy mass of greenery.

423. Wisteria is another climber that finds great favor in all parts of the world. It is a member of the pea family, as can readily be seen by the pea-shaped flowers. The flowers are borne in clusters which in many cases are over a foot in length and of strikingly beautiful appearance. The leaves are compound and resemble those of many other members of this family. The plant is a great favorite in Japan where it is used very extensively and where its cultivation has been brought to a high state of excellence. The Japanese give especial attention to the pruning for flowers. They are so successful in this respect that the flower clusters are sometimes two or three feet in length.

The rigid stems of the plant may be trained over pergolas with especially fine effect; and this is often done. Sometimes the stems are pruned back and the plant assumes the habit of a shrub. When this is the case, the wisteria presents a striking appearance with its many clusters of purplish flowers.¹

424. Shrubs.—Such a variety of shrubs is available for planting and the different situations in the landscape are so exacting in their individual requirements that it is difficult to suggest a few shrubs which would serve all purposes.

425. Bridal wreath is one of the commonest of all shrubs and is found in widely separated sections of the United States. The technical name is *Spiræa Vanhouttei*. It is a member of the rose family and is grown primarily for its fine mass of white blossoms which cover the plant in dense clusters in the early spring. (Plate VIII.) The shrub is deciduous, but in the warmer parts of the United States retains some of its foliage during the winter. It is not high-growing, attaining a maximum height of five to six feet. It makes an ex-

¹ There are other colors besides the purple, among them white, pink, and blue.

cellent shrub for massed plantings about the bases of buildings or as a border for lawns or in similar situations.

426. Viburnum.—One of the best known members of this genus is *Viburnum Opulus*, commonly called snowball. The flowers are borne in dense spherical clusters and make a very showy appearance.

Another ornamental species is *Viburnum Tinus*, the common name of which is Laurestinus. This is frequently kept closely clipped and used as a hedge plant, but may be allowed to grow to its full height. It attains a maximum height of twelve or fifteen feet. Viburnum is a member of the same family as the honeysuckle and the leaves strongly resemble those of the latter, although the habit of growth of the two is entirely different. The viburnum is easily propagated from seed and, since it is grown with very little care, it is very commonly used as an ornamental plant.

427. Barberry.¹—A number of species of barberry are used as ornamental plants in North America. The technical name is *Berberis*. One of the species, *Berberis Thunbergii*, is a low dense shrub with brilliant foliage and bright berries; it is an excellent ornamental where low-growing material is desired. One of the points especially in its favor is that it is fairly tolerant of shade, although it grows also very well in bright sunlight. A closely related form, sometimes called *Berberis Aquifolium* but usually classed as a separate genus under the name *Mahonia Aquifolium*, is the state flower of Oregon. This plant is also rather tolerant of shade and is characterized by glossy bronze-green foliage and yellow flowers. It is a very handsome shrub growing somewhat higher than *Berberis Thunbergii*.

428. Philadelphus.—Among the higher-growing shrubs, one of the most popular is mock orange or syringa. There are

¹ In wheat-growing areas of the United States, it must be remembered that the barberry is an intermediary host for the common wheat rust and its use as an ornamental plant should, therefore, be avoided.

several species, the more common being probably *Philadelphus coronarius*. The shrub is deciduous and the species mentioned above grows to a height of eight to twelve feet. The flowers are white with yellow centers and, while they resemble in a general way the flowers of the orange (hence the name mock orange), they are much larger and more showy.

The members of this genus are found in widely separated parts of the world; some of the forms come from China, some from the Himalayas, others from Mexico and still others are wild in the United States.

429. Hydrangea is essentially a shade-loving plant. There are many different forms, most of them shrubs, but a few are climbing vines. They are deciduous and are characterized by rather large leaves and flowers borne in dense heads or clusters. These flowers are commonly pink in color but they can be changed from pink to blue by the addition of iron or lampblack to the soil. The hydrangea is propagated readily from cuttings and grows rapidly but requires a fairly moist and rich soil for best development. Most of the ornamental forms should be pruned rather heavily every winter and some of them are rather susceptible to frost. The species should, therefore, be selected with some care, keeping in mind the experience of the individual community.

430. Trees.—So many trees are suitable for landscape-gardening purposes that it is out of the question even to attempt to suggest a few as being preferable to others. The oak is found in all the parts of the United States. There are both deciduous and evergreen species and the plants differ in size from small shrubs to very large trees. A number of plants bear the name of oak which in a botanical sense have no relationship whatever. Poison oak, for example, belongs to an entirely different group of plants, and Australian silk oak, technically known as *Grevillea robusta*, does not even resemble the oak with respect to flower, leaf, or habit of tree.

There are several kinds of elm, some of them native to

North America. This is one of the grandest trees and is extensively used in ornamental planting. The maple, known technically as *Acer*, has several species native to North America and, like the elm, is magnificent for ornamental purposes. There are also a large number of coniferous trees: spruce, hemlock, fir, cypress, and others, some of them native to North America and some imported from other countries. In general, the landscape-gardener will attain good results by using plants native to the locality where he is working, but this should not prevent his drawing on the rich abundance of material which is available from foreign lands.

431. Lawn grasses.—The most important single factor of the landscape is the lawn or open space. It is the center about which the whole plan is drawn. If properly prepared, no feature of the landscape is more beautiful, but if neglected, it will show defect very quickly. The first thought of the landscape-gardener should, therefore, be to have the ground in the best possible condition as regards both texture and richness of the soil, as well as evenness of surface.

A large number of different grasses are available for lawn-planting and the choice will depend to a considerable extent on the experience of the community. Kentucky blue-grass alone or in combination with white clover is used with success in many sections of North America. In some parts of the South, Bermuda-grass is practically the only material which can be employed since it grows so readily as to displace any other plant. The objection to Bermuda-grass is its appearance in the winter, as the leaves turn light brown, and the lawn appears dead during a considerable portion of the year.

Another plant sometimes used, especially in the warmer parts of California, is *Lippia canescens*. This thrives under circumstances so unfavorable that no other material could live. It endures a great amount of drought and persists each year even when subject to much tramping. On that account it is commonly used in school-yards. The plant is a trailer,

forming a dense mat on the ground and is characterized by gray-green leaves and small purplish-white flowers. It does not require mowing unless it is desired to keep the flowers removed. A lawn of this material never has the beautiful appearance of well kept Kentucky blue-grass.

One interesting point regarding *Lippia canescens* is that it is established in the first place from cuttings, as very few seeds are produced. These cuttings are put in the ground a few inches or even a foot apart, and spread quickly until they form a carpet.

432. Ground cover.—Frequently it is desired to have the space under trees and shrubbery covered with a solid mass of green material. A number of plants can be used for this purpose; the requirements are that they grow fairly rapidly in the shade and form a mat of foliage. The two most commonly used for this purpose are English ivy and *Vinca minor* or periwinkle. Both of these are evergreens which thrive in moist shady situations.

THE LANDSCAPE PLAN

With the material the landscape-gardener has at his disposal, he can produce widely varying effects. The type of plants which he uses and the way he groups them gives to the landscape that particular quality which is known as "style."

433. Formal style.—There has always been a tendency, happily much more common formerly than now, to arrange grounds after the manner of definite geometrical designs, as though a garden were an illustration of a Euclidian proposition. In this style of landscape-gardening, all lines are perfectly straight, or assume the forms of circles, five-pointed stars or triangles, or other regular figures. The hedges are kept closely clipped, the shrubs are trimmed into odd and sometimes grotesque shapes. Flowers and other ornamental plants may be used, but the vegetation is invariably sub-

ordinated to the design. Some of the most famous gardens of the Old World and of early colonial days¹ were of this sort; and many have tried to copy the idea in a small way on their home grounds.

The result needs no description, for it can be observed at first hand in almost every town and village of the country. Grounds laid out in this way demand constant care, and when neglected they very soon have a run-down appearance. There is a field, sometimes, for formal gardening of this sort, but not for the average American home grounds.

434. The natural style.—In direct contrast to the highly artificial effect of the formal gardens are the graceful unconsciously beautiful lines of the natural style. This type takes its inspiration from the out-of-doors, from the mountains and woods, and meadows; from the landscape-gardening of nature itself.

“In this connection,” says John McLaren,² “it is suggested that some consideration be given to what may be termed the happy accidents of nature’s plantings, for in some of the untouched virgin spots in nature’s garden there are scenes more soft and more beautiful than anything our gardening has yet produced. Those who have undertaken to do what we are now considering, that is, to plant a pleasure garden and lawns, and are in doubt as to how to establish the lines of the lawns or groups of trees, shrubs and flowers, may get invaluable suggestions as to how to arrange them in harmonious composition if they will do as our best painters do—namely, go into the natural forests of our hills and hillsides, or the meadows and baughs of our valleys, and select, from the innumerable beautiful scenes, the one whose beauty most appeals to them and which seems to best fit the general outline of the site for which the plans are being prepared. Then let the measurements of this part of nature’s garden be care-

¹ See *Standard Cyclopedia of Horticulture*, Vol. III, plate XLVI.

² *Gardening in California, Landscape and Flower*.

fully taken, figuring what are its length, and its breadth; what are the depth and width of the grassy bays which seem to meander through the forest; also the form and shape which these bays assume. It will be found that nature seldom runs straight lines and shaped curves. Let the woody promontories be measured, figuring how far each one projects into the meadow and noting how nature has done its planting—how far one tree is from the other, and how harmonious the whole plan is.

“After having sketched into a map all of the trees with their names and characteristics, the different shrub-growths should next be similarly studied and sketched in, especially noting how they are distributed. After these, and any other data which seem to be of importance in the general effect, are carefully platted, let this rough sketch be laid out to scale and reduced or enlarged to fit the plan for the proposed grounds. If the propositions of the original are faithfully carried out and initiated in the form and outlines of the lawns and in the character and planting of the trees and undergrowths, the result will be a delight to the owner, and an artistically laid out property.”

EXERCISES

EXERCISE I.—Plant materials.

Materials.—Secure specimen plants of *Spiræa*, *Mahonia*, *Hydrangea*, *Parthenocissus*, *Wisteria*, *Viburnum*, *Philadelphus*, or any other ornamental shrubs and climbing vines of the locality.

Procedure.—Make drawings of leaves and if possible of flowers of each of the shrubs and vines obtained for study. In connection with these drawings, make permanent notes featuring the following points: Size of shrub when mature, kind of wood used for cuttings, special points on propagation, situations to which the plant in question is adapted, general appearance and desirability for landscape-gardening purposes.¹

¹ To the Instructor: This exercise may easily be extended to cover a dozen or more laboratory periods, if desired, and should include trees and possibly flowering plants as well as shrubs and vines.

EXERCISE II.—The landscape plan: A project.

Each student should beautify all or a portion of his own home grounds, making a drawing to scale in the class, indicating the shrubs, vines, and other material which he plans to use. He should then, under the direction of the instructor, put the grounds into shape and set out the plants.

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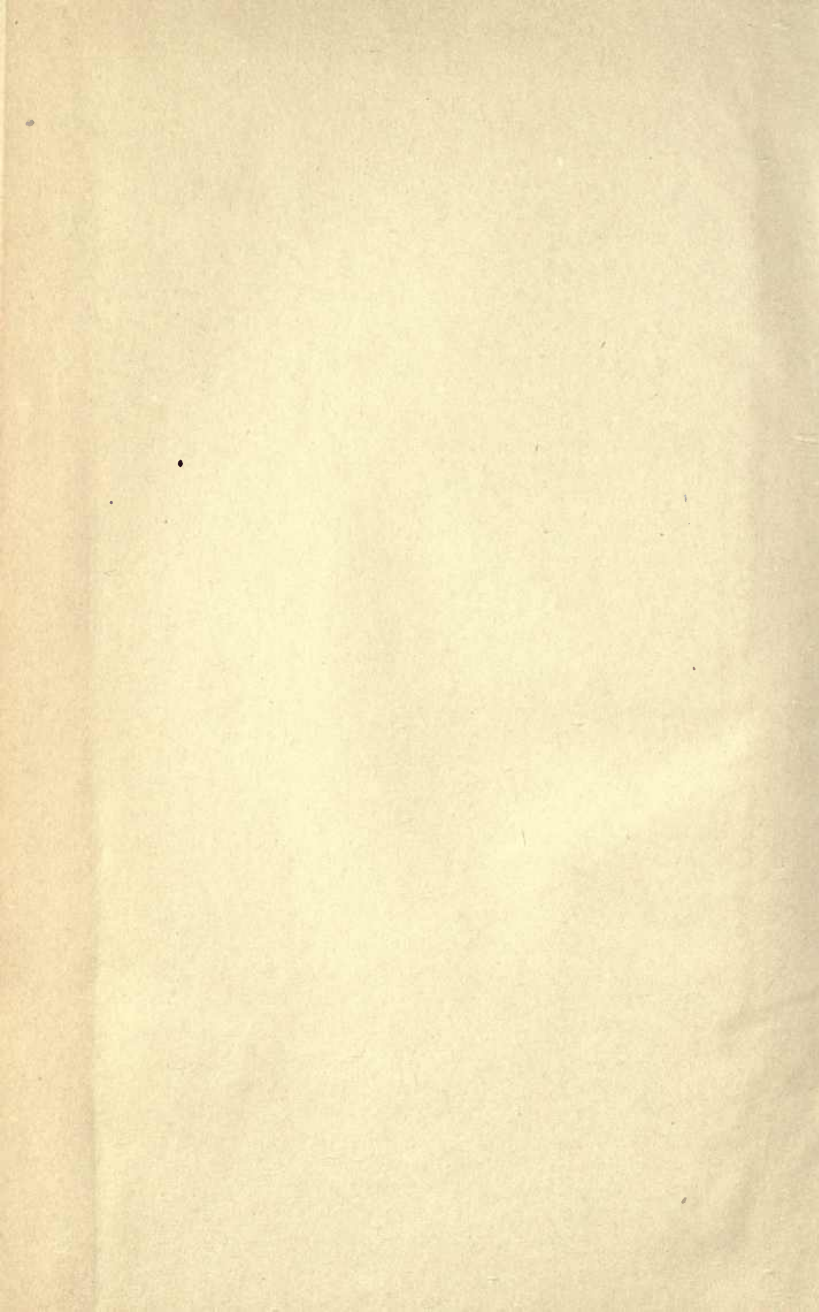
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